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ABSTRACT

Acid pollution is a major international problem, but the debate it has elicited has often clouded the distinction between myth and facts. This publication attempts to concerning the acid pollution situation. This publication attempts to identify available facts. It is the first global review of the problem of acid pollution and the first to comprehensively examine the potential for acid pollution in developing countries. Specific topic areas addressed include: (1) the chemistry and formation of acid pollution; (2) acid damage (identifying the impacts on forests, plants and crops, lakes, rivers and fish, human health, and building corrosion); (3) acid pollution reduction and control (reviewing management strategies); (4) international implications (evaluating the political considerations and control agreements); and (5) individual country profiles (outlining the position and conditions of acid pollution in 39 key countries). (ML)

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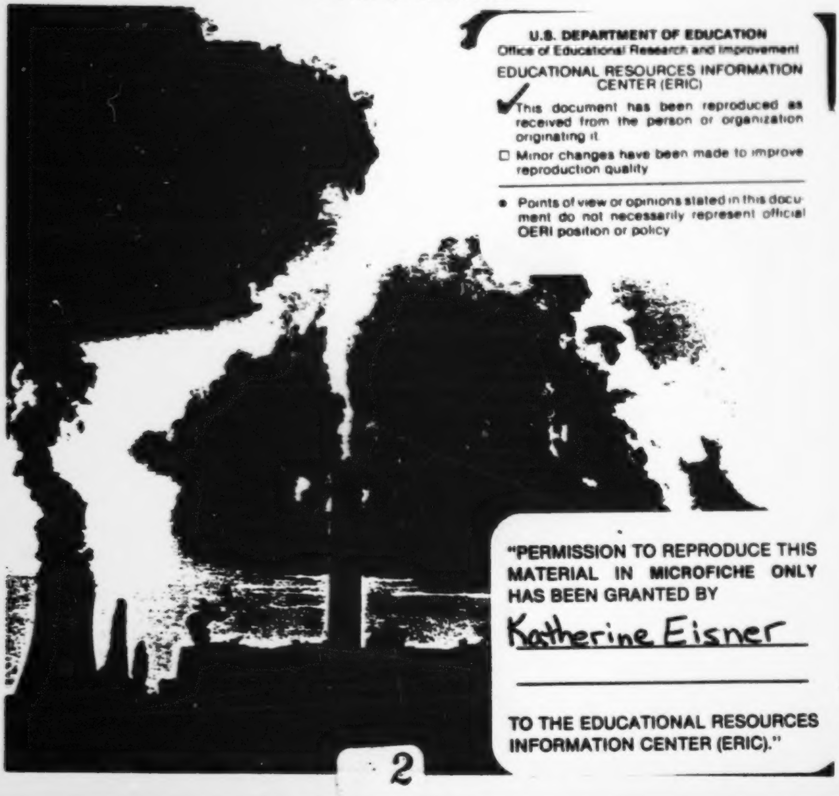
ACID EARTH

The global threat of acid pollution

John McCormick



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ACID EARTH

the global threat of acid pollution

by
John McCormick

edited by Jon Tinker

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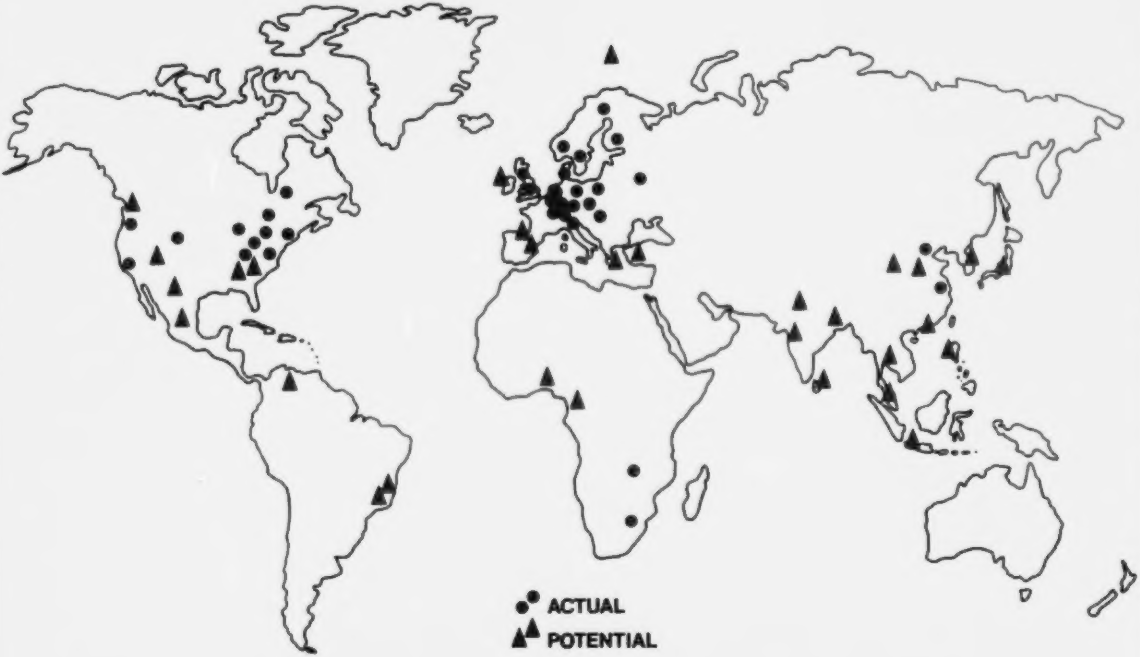


Global acid pollution

Introduction

In 1872, a British chemist discovered a link between acid in rain falling near Manchester and the sulphur dioxide given off when coal was burned.

Seventy years later, research in Europe confirmed his discovery. Sulphur and nitrogen oxides produced when oil, coal, natural gas or peat are burned can be converted in the atmosphere into sulphates and nitrates, and then into acids, which can return to earth in contaminated rain, snow, hail, fog or mist. Thus the phrase 'acid rain' entered the language. It was an evocative, convenient and dramatic term, but not altogether accurate.

'Acid rain' is today used indiscriminately to describe different kinds of pollution associated with the burning of fossil fuels. But, as Martin Holdgate, chief scientist of Britain's Department of the Environment, observes: "It is clear that acid deposition is a much broader process than has often been assumed, involving interactions between many atmospheric pollutants and several pathways. We ought to stop describing it by the generic term 'acid rain'". [1]

Acid pollution can be wet (rain, snow, mist) or dry (gases, particles, smog). It involves not only sulphur dioxide but nitrogen oxides, hydrocarbons and ozone, acting alone or together. The pollution itself is not always 'acid', but may trigger off acidification in soils, lakes and rivers.

The effects of acid pollution sound a now familiar litany. Trees are being damaged, and soils left too acid to support plants. More than half West Germany's forests are affected, and the German fir is close to extinction. In nine other European countries, forests are damaged. In parts of Europe and the United States, acid pollution has cut crop yields. Eleven European countries may be losing crops worth as much as $500 million per year.

Lakes are being acidified by acid water flowing off surrounding land. In Sweden, one lake in five has turned acid, and in Ontario, Canada, nearly 50,000 lakes are vulnerable. Fish and aquatic plants are dying.

In smog-bound cities throughout the world, people with respiratory and heart complaints are ailing, even dying, from acid smoke and dust pollution. The deaths of at least 4,000 people were hastened by the infamous winter smog of 1952 in London. In two days in August 1984, 500 Athenians were hospitalised following a smog so severe that emergency government measures had to be imposed to protect the health of the population. In Mexico City the mayor has warned of 'collective hysteria' unless dramatic action is taken to reduce air pollution.

Stone buildings are being eaten away. In parts of Poland, railway tracks have been so corroded that trains cannot travel faster than 40 kph (25 mph), and the gold on the roof of Kraków's cathedral chapel is dissolving Acid pollution may be causing much of the corrosion to cars in Canada.

The problem is not confined to Europe and North America. China — the world's third biggest emitter of acid-forming sulphur dioxide (after the USSR and the United States) — has its own acid pollution problems, and winds may be blowing the pollution to Japan. In India, the Taj Mahal is dissolving in an acid wind. Acid deposition has been found downwind of the Zambian Copperbelt. In Johannesburg buildings are corroding. Soil samples from São Paulo state in Brazil have shown unusually high acid levels. In the Arctic, atmospheric haze has turned experimental filters 'flannel grey' and 'sooty black'.

Because fossil fuel emissions in one country are often converted into acid deposition in another, acid pollution has become a major international issue. Scandinavian governments are critical of Britain's unwillingness to curb its pollutive emissions. In March 1984 Canadian government officials said US inaction on acid pollution was "one of the biggest irritants in US-Canadian relations". At the Reagan-Mulroney summit in March 1985, acid pollution was at the top of the agenda, and turned out to be one of the few issues on which Canada and the United States could not agree.

In 1977, Canada's then Minister for Environment, Romeo LeBlanc, described acid pollution as "an environmental time bomb". In 1981, his successor John Roberts said that it was "a striking paradigm for so many of our environmental problems. Its scope is international. Its causes are scattered in a variety of countries. Its consequences extend far beyond national boundaries. And its successful resolution will require cooperative international action." [2]

There has been some international cooperation. In 1979 an international convention on long-range transboundary pollution was opened for signature, and in 1984 the Ottawa conference on acidification resulted in the formation of the '30% Club', member countries pledging to reduce their national emissions of acid-forming sulphur dioxide by at least 30% in 10 years. But the reductions agreed under the terms of the convention and by the 30% Club are by no means the final answer. Both coal use and overall energy consumption may triple worldwide over the next 40 years. [3]

Research has attempted to clarify the causes, effects and scale of acid pollution, but has produced little scientific or political agreement. Monitoring and data gathering systems differ from one country to the next. Even within countries, data from government, industry and science may not agree. New theories about sources and effects emerge constantly. West German scientists studying forest dieback have outlined theories involving as many as 160 different causative factors.

This lack of agreement is often used by governments and industry as an excuse for taking no action. Two of the biggest sulphur dioxide-producing countries in the world — the United States and Britain — have traditionally argued that the uncertainties are too great to warrant the expense of treating fuels to reduce their sulphur content, of treating gases given off by combustion, or of attaching filters to vehicle exhausts.

By contrast, the countries that most feel the effects of acid pollution and acidification — such as West Germany, Sweden and Canada — have already taken some corrective action even though they may agree that the evidence is uncertain.

In early 1983, Canadian environment minister John Roberts argued that there was enough information to act, and that it was no longer a question of science, but of political will: "We have reached the point where a decision to stall and drag our feet on the pretext that we need more research is, in fact, a decision to do nothing".

The 1984 British House of Commons environment committee report on acid pollution warned that "immediate and hard financial decisions have to be taken as time is running out... Enough is now known to justify the development and application of technology for removing the causes and effects now abundantly apparent." [4]

In July 1985, UN Environment Programme director Mostafa Tolba said that the public was "right to expect governments to take ameliorative action. And they are right to be impatient, if not suspicious, when action is delayed pending further research."

Normally cautious scientists too are demanding action. In 1981 the US National Research Council concluded that what was then known about acid pollution was "disturbing enough to merit prompt tightening of restrictions on atmospheric emissions of fossil fuels and other large sources".

In 1983, a scientific panel appointed by the Reagan administration's Office of Science and Technology Policy pointed out that "if we take the conservative point of view that we must wait until the scientific knowledge is definitive, the accumulated deposition and damaged environment may reach the point of 'irreversibility'". [5]

Acid pollution is a major international problem, but the emotional and often angry debate it has elicited between governments and non-governmental organisations, and among governments, has often clouded the distinction between fact and fiction. It is prone to myth and misconception.

Acid earth is a response to those myths. It begins by looking at the chemistry of acid pollution and showing a little of the complex mechanisms through which sulphur and nitrogen oxides are converted to acid. Then it examines ways of reducing emissions and assesses the politics and international control agreements. Finally, it outlines the position in 39 key countries from every region of the world.

Acid earth is the first global review of the problem of acid pollution, the first to begin making a distinction between different kinds of acid pollution, and the first to comprehensively review the potential for acid pollution in developing countries. It begins sorting the fact from the fiction.

Chapter 1

The formation of acids

Acid pollution is a reality, and is both a national and an international problem. How acids are formed in the atmosphere is now much better understood and there is some scientific consensus emerging over the relationship between pollutive emissions and acid deposition. But there is much less agreement about how acid actually damages plants, trees, crops, lakes, fish, buildings or people. How much of the observed damage is due to acid pollution, and how much to other factors, is still hotly debated. The unanswered questions continue to be used as a major argument by governments opposed to taking action to control acid pollution.

The steady flow of new theories about the relative role of different pollutants is just one symptom of the confusion. Until recently, sulphur dioxide was regarded as the main problem. Now more attention is being paid to the role of ozone, and to road traffic as a source of nitrogen oxides. Chemical reactions in the air between nitrogen oxides and hydrocarbons, driven by the sun's energy, produce ozone which, although not strictly part of the acidifying process, contributes to environmental damage.

What is certain is that a variety of gases and particles are implicated in acid pollution and acidification; that sulphur dioxide (SO_2) and nitrogen oxides (NO_x) can be converted in the atmosphere into sulphuric and nitric acids; and that — depending on a variety of biological, chemical and meteorological factors — soils, forests, lakes, rivers, animal and plant life, and buildings are susceptible in varying degrees to the effects of these pollutants. The scientific debate is centred around three issues: causes, effects, and the scale of the problem.

There are three main links in the acid pollution chain:

1. *Emission* —the emission of the gases and particles that are the raw ingredients of acid pollution.
2. *Transport, transformation and deposition* — the passage of gases and particles in the atmosphere, their conversion to acids, and their return to earth.
3. *Pollution* — the consequent environmental effects.

1. Emission

All plants and animals contain some sulphur absorbed from their environment. Several hundred million years ago, fossil fuels were formed when dead animals and plants decomposed and were broken down into liquids (oil), gases (natural gas) and solids (coal and peat). In the same swamps and sediments, mineral sulphides (pyrites) were formed, probably by bacteria.

When sulphide ores are 'smelted' (roasted) to extract metal, sulphur dioxide is emitted. And when fossil fuels are burned, the long-stored sulphur is also released as sulphur dioxide. The sulphur content of oil and coal varies, depending largely on where it comes from. Crude oil may have anything from 0.1% to 3% sulphur content, staying roughly uniform according to the geographical location of the oil. Coal, by contrast, can have a sulphur content of anything from 0.4% to 5%, and is by no means uniform according to source; the sulphur content varies from one grade to the next, and even from one seam to the next in the same mine, reflecting local variations in ecological conditions millions of years ago.

'Hard' coals such as anthracite are normally low in sulphur, while 'soft' coals (bituminous, sub-bituminous and lignite/brown coal) can be much higher. But there are exceptions: while most soft British and southern Brazilian coal has a sulphur content of up to 3%, most of the soft brown coal mined in West Germany's Rheinland has a sulphur content of less than 1%. [6]

According to the US National Research Council (NRC), nearly half the SO_2 in the atmosphere is natural. But about 100 million tonnes are emitted every year from coal or oil-fired power stations, industries that use fossil fuels, and metal smelting. The geographical concentration of man-made SO_2 varies, with the highest levels in the industrial centres of Europe, North America and eastern Asia. A major Norwegian research project in the 1970s concluded that 90% of the SO_2 in the air over Western Europe was man-made. Given the world's reserves of fossil fuels, there are huge quantities of SO_2 that could theoretically be released in the future into the atmosphere by combustion.

In Britain and the United States coal-fired power stations account for two-thirds of man-made SO_2 emissions. In West Germany they account for half. In Canada smelters account for 63% of emissions. The largest single source of man-made SO_2 in the world is the copper and nickel smelting complex at Sudbury, Ontario, which annually produces 632,000 tonnes of SO_2. The Sudbury nickel smelter alone is estimated to have emitted more SO_2 in the period 1969-79 than all the volcanoes in the history of the earth. [7] SO_2 emissions in Europe probably doubled between 1950 and 1973 and peaked in 1975-78; since then, they have remained steady or even declined in some countries. Emissions in the

	SO_2 emissions	*Sulphur deposition (%)*		
	('000 tonnes)	*Foreign*	*Domestic*	*Undecided*
Twelve largest (world):				
USSR	25,000	32	53	15
United States	24,100	—	—	—
China	12,000	—	—	—
United Kingdom*	4,680	12	79	9
Canada	4,516	c50	50	—
East Germany	4,000	32	65	3
Italy*	3,800	22	70	8
France*	3,270	34	52	14
West Germany*	3,200	45	48	7
Czechoslovakia	3,100	56	37	7
Yugoslavia	3,000	41	51	8
Poland	2,755	52	42	6
EEC total (inc. * above)	17,596	—	—	—
Others:				
Spain	2,730 (1985)	18	63	19
Hungary	1,633	52	42	4
Finland	595	55	26	19
Sweden	496	58	18	24
Norway	137	63	8	29
Mount St Helens (1980-81)	300	—	—	—
TOTAL (world)	Approx. 100 million tonnes			

Figure 1. Annual SO_2 emissions and sulphur deposition in selected countries (1980). Sources: Data on SO_2 emissions are variable, reflecting the different data-gathering techniques used by different countries. For many countries, the figures are either estimates or are not available at all. The figures above come from a variety of sources, including the EMEP programme for monitoring and evaluating long-range transmission of air pollution (1981), the UN Economic Commission for Europe (1982), and miscellaneous sources. Some countries have published more recent figures, but 1981 is the latest year for which comparable figures are available for most of the countries listed here.

eastern US rose from about 12 million tonnes in 1950 to about 24 million tonnes in 1965, and stabilised at that level. In Canada more than 4.5 million tonnes are emitted yearly, the same as in the mid-1950s. China — with annual estimated emissions of 12-15 million tonnes — is the third largest source of SO_2 after the USSR and the United States.

Burning fossil fuel is also the major source of man-made nitrogen oxides, the second major element in acid pollution. Combustion oxidises both the nitrogen in fuel (bituminous coal has an average nitrogen content of 1.5%) and some of the nitrogen naturally present in the air (which is 80% nitrogen). The quantity and composition of the nitrogen oxides formed depends on how combustion is performed and at what temperatures. Combustion will normally oxidise 5-40% of the nitrogen in coal, 40-50% of that in heavy oil, and nearly 100% of that in light oil and gas. The higher the temperature, the more nitrogen oxides are formed.

Power stations which burn fossil fuels are the major source of nitrogen oxides in developed countries, but road traffic makes a substantial contribution, particularly in larger cities. Not all countries can provide detailed information on their NO_x emissions, but in Western Europe some 30-50% of the emissions come from motor vehicles. About 30-40% come from power plants, mainly coal-fired plants. In 1980, 44% of NO_x emissions in the US and 61% in Canada came from transport. Eastern Europe has lower NO_x emissions, but it also has fewer cars than the West, and the types of vehicles and the quality of roads (which affects speeds, and therefore emissions) differ. In the Third World, vehicles are usually the main source of NO_x.

The burning of fossil fuels accounts for about 60-70% of man-made atmospheric nitrogen compounds in Sweden. The rest come from agriculture and forestry, both of which use much nitrate-based fertiliser. Anything from 10% to 75% of the nitrate can evaporate, depending on conditions when the fertiliser is spread.

Because there has been no systematic monitoring of NO_x emissions, it is difficult to give exact figures on present and future levels. In some countries, such as the United Kingdom and Sweden, NO_x levels have remained roughly stable over the past decade. In others, such as West Germany, they have risen sharply. In 1980 it was estimated that 9.2 million tonnes of nitrogen oxides were emitted in Europe; by the year 2000 the figure could be just over 11 million tonnes. If effective measures are taken in Central Europe, in particular to fit catalytic converters to cars and limit speeds, the increase could be slower and lower. NO_x emissions in North America were around 21 million tonnes in 1980; about 19.3 million in the USA and about 1.8 million in Canada.

As with sulphur dioxide, about half the nitrogen oxides in the earth's atmosphere are man-made, but again the proportion is much greater in the industrialised North. In Europe and North America, man-made NO_x

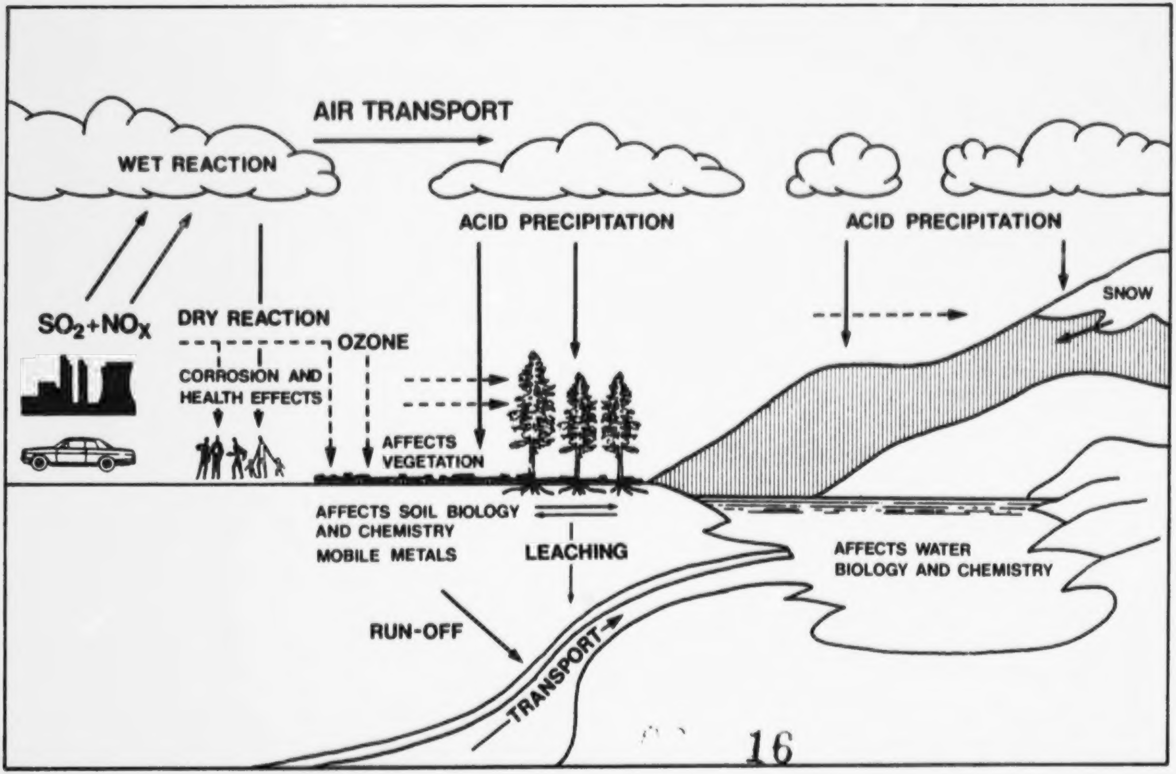
Öko Freiburg

Coal-fired power station, West Germany. Up to 90% of the sulphur dioxide in the air over western Europe is man-made. Two-thirds of the sulphur dioxide (and a third of the nitrogen oxides) comes from coal-fired power stations.

outweighs natural NO_x by 5-10 times. [8] The proportion of NO_x in the atmosphere in Europe is thought to have grown by 40-50% during the 1970s, but rates vary. [9]

NO_x is a critical factor in many Third World cities, where a combination of heavy road traffic and local wind patterns can often recirculate nitrogen oxides and other pollutants, creating severe photochemical smog. Such air pollution is now regarded as 'normal' in Brazil's largest cities. The still and stable air over many Southeast Asian cities creates ideal conditions for the build-up of pollutants from road traffic and industry.

There is some hope of reduced SO_2 emissions in the Northern Hemisphere as a whole, but there is less reason to be optimistic about NO_x emissions until effective action is taken to cut emissions from road vehicles and power stations.


AIR TRANSPORT
WET REACTION
ACID PRECIPITATION
ACID PRECIPITATION
SNOW
SO_2+NO_X
DRY REACTION
OZONE
CORROSION AND HEALTH EFFECTS
AFFECTS VEGETATION
AFFECTS SOIL BIOLOGY AND CHEMISTRY
MOBILE METALS
LEACHING
AFFECTS WATER BIOLOGY AND CHEMISTRY
RUN-OFF
TRANSPORT

2. Transport, transformation and deposition

Once in the atmosphere, the sulphur and nitrogen oxides undergo complex chemical processes that transform them into gaseous or liquid forms of sulphuric acid (H_2SO_4) and nitric acid (HNO_3). The amount of acid produced depends on weather conditions such as wind, cloud cover, humidity, sunlight, and on the presence of other pollutants.

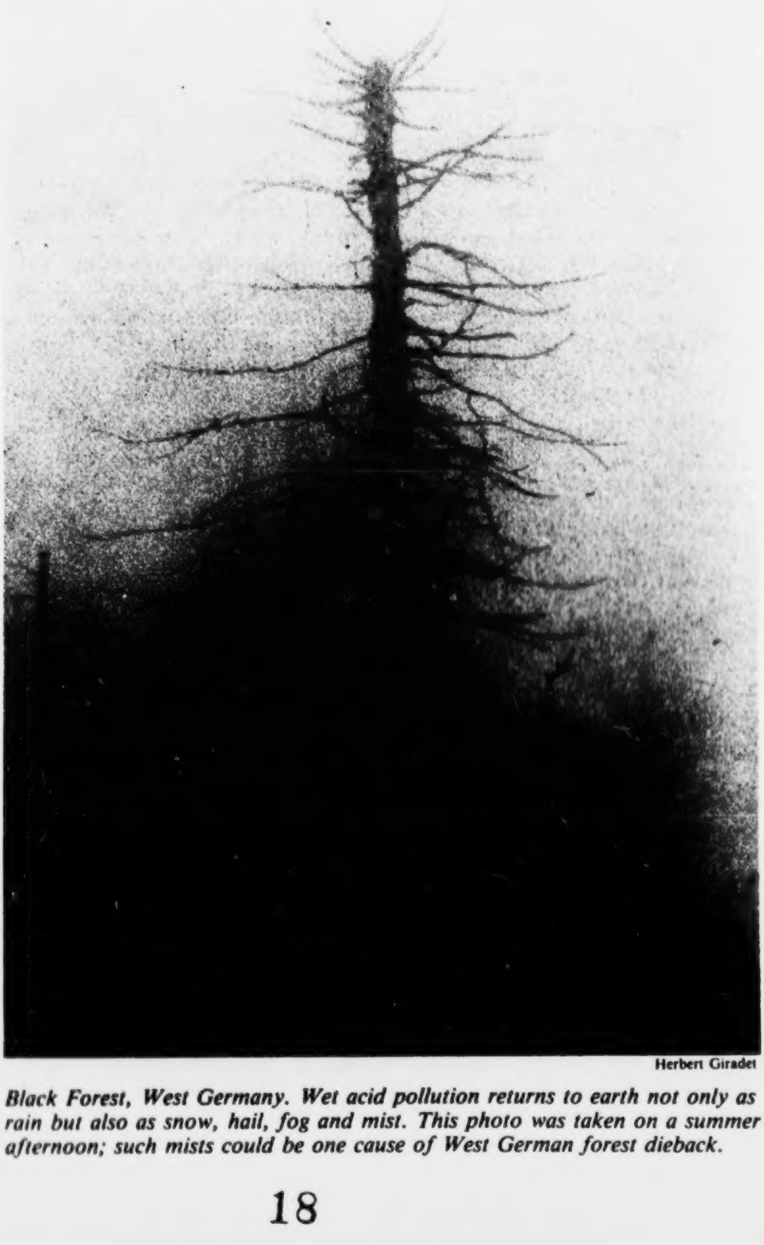
There are two phases involved in the formation of acids — dry and wet. In both, SO_2 and NO_x are converted to sulphate and nitrate. Dry or 'gas phase' conversion predominates in the vicinity of emission sources, whereas wet or 'aqueous phase' conversion involving reactions within water droplets is more predominant at a greater distance. Dry phase SO_2, NO_x, sulphates and nitrates return to earth by direct deposition on surfaces in the form of gases and particles, especially in the vicinity of the sources (i.e. within 300 km/190 miles). This is known as dry deposition. The rest of the oxides, converted to acids by wet or 'aqueous phase' reactions, eventually return to earth as acid rain, hail, snow, sleet or fog. This is known as wet deposition.

In the gas phase, oxide can be converted to acid in several ways, usually with the help of a catalyst such as a photochemically generated radical (an atom or group of atoms containing one or more unpaired electrons: they exist for only a brief period of time before reacting to produce a stable molecule). Because these radicals are formed under the influence of sunlight, sunny weather encourages conversion to acid; the rate of conversion falls off rapidly after sunset. In the gas phase, there are several reactions that can lead to the formation of sulphuric acid (H_2SO_4), the most important of which seems to be that between SO_2 and the hydroxy radical HO, which ultimately produces H_2SO_4. HO is also the main agent for oxidising nitrogen dioxide (NO_2) into nitric acid (HNO_3).

HO itself can be formed in several ways, the most common being via a complex reaction involving ozone. Nitrogen dioxide can be broken down by sunlight, forming a highly reactive oxygen atom which combines with diatomic oxygen molecules to form ozone (O_3), an unstable form of oxygen containing three instead of two atoms per molecule. When ozone breaks down, excited oxygen atoms are released and may react with water to produce HO.

The rates at which the acids are formed is thought to depend on the concentrations of HO present. Direct measurement of HO in the atmosphere is difficult, but the US National Research Council has estimated the rates of conversion of SO_2 and NO_2 respectively at 16.4% and 150% per day on polluted sunny summer days — when HO concentrations are high — and 3% and 25% per day on polluted sunny winter days — when the concentrations are lower.

In dry deposition, pollutants can return to earth as oxides and be



Herbert Giradet

Black Forest, West Germany. Wet acid pollution returns to earth not only as rain but also as snow, hail, fog and mist. This photo was taken on a summer afternoon; such mists could be one cause of West German forest dieback.

converted to acid through adsorption (where a gas accumulates on the surface of a solid) or absorption (where SO_2 and NO_x can enter the stomata — the leaf pores that control the passage of gases into and out of a plant — and be oxidised to acid inside the leaf). Acids can also be formed directly on the surface of vegetation or on the ground when dry-deposited material is dissolved in rain or snow.

Dry deposition is the simplest form of acid pollution, but is still not completely understood. Roughly a third of sulphur emissions from the northeastern US are thought to be dry deposited. [10] The oxides in industrial emissions, particularly those in hot gases given off by smelters or power plants, can rise to altitudes of several hundred metres. At that height, the average wind speed is about 36 kph (22 mph) — fast enough to cover the distance from Pittsburgh (US) to Quebec (Canada) in 24 hours, or London (UK) to Gothenburg (Sweden) in 36 hours.

The longer the pollutants stay in the atmosphere, the greater the proportion converted to acid sulphate and nitrate. The time they are airborne and the distance they are carried depends on several factors, from the height of smokestacks to wind and weather conditions. With a strong wind, the oxides and acids can stay in the atmosphere for several days, and be carried several hundred kilometres, often across national borders.

Because the prevailing winds in Europe and North America blow from the southwest to the northeast, the major routes of airborne pollution are from the UK and Eastern Europe to Scandinavia, and from the United States to Canada. Winds also carry pollution across the US-Mexican border (both ways), and from China to Japan.

In the aqueous phase reaction, which has been studied intensively but is still open to some dispute, SO_2 and water turns rapidly to acid. The presence of water vapour is essential, and oxidation on a cloudy day will be more rapid than on a clear day. The presence of trace metal catalysts or strong oxidising agents is also vital. Manganese seems to be the only metal that can act as a catalyst in cloud droplets, although this is still uncertain. Conversion to acid is faster when there are oxidising agents such as ozone or hydrogen peroxide (H_2O_2) present.

Much less is known about the aqueous phase formation of nitric acid, but ozone is certainly sometimes involved.

Measuring acidity. Acids are chemical substances which, in water, provide positively charged hydrogen ions. Sulphuric acid consists of sulphate and hydrogen ions, and nitric acid of nitrate and hydrogen ions.

The degree of acidity or alkalinity of a liquid is measured on the pH scale (see Figure 2). This ranges from 0 to 14, with 0 being the most acid (battery acid has a pH of 1), 7 being neutral (the pH of distilled water) and 14 the most alkaline (a saturated solution of ammonia in water has a pH of 11). The scale is logarithmic, which means that a step of a single number increases or decreases acidity by a factor of 10. So a solution with

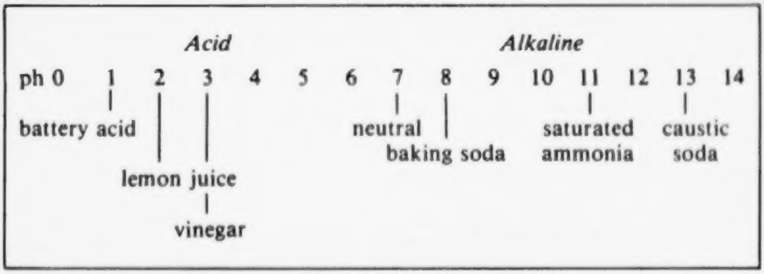


Figure 2. The pH Scale.

a pH of 6 is 10 times more acidic than one with a pH of 7, and a solution with a pH of 5 is a hundred times more acidic. Similarly, a solution with a pH of 8 is 10 times more alkaline than one with a pH of 7.

All rain is slightly acidic because of the natural carbon dioxide (CO_2) content of air. Dissolved in water, CO_2 forms carbonic acid, a weak acid. So while distilled 'pure' water has a pH of 7, 'normal' or unpolluted rainwater (i.e. water in equilibrium with atmospheric carbon dioxide) has a pH of about 5.6, although the presence of naturally occurring SO_2, ammonia, organic compounds or dust can cause 'normal' pH values of between 4.9 and 6.5. [11] Some acid in rainwater is useful in helping water dissolve soil minerals, making them available to plant and animal life. Acidity is often neutralised by the soil itself, for example by the alkaline carbonates in limestone.

But higher levels of acidity become destructive. Rainwater during a storm in Pitlochry, Scotland, in April 1974 had a pH of 2.4 — similar to vinegar. An even lower pH value was unofficially recorded in rain during a 1978 storm in Wheeling, West Virginia, when the pH of the rain fell below 2.0, making it more acid than lemon juice.

Some water and soils are naturally acid. Small pools in upland *Sphagnum* (a species of moss found in swamps and fens) bogs commonly have a pH of 3-4, but only a fraction of this can be attributed to pollution. There are some larger naturally acidic lakes in Sweden with a pH of 4.5, but they are exceptions to the rule. Surface water (lakes, streams, seas) normally has a pH of 6-9. Lakes in areas with bedrocks that do not weather easily or where the surrounding soils are low in lime content can have a 'natural' pH of 6. Such lakes are also low in nutrients. In favourable summer conditions, the pH of nutrient-rich lakes in lime-rich areas can be as high as 9.

Ozone. Where the air temperature is greater than 15°C (59°F), the nitrogen oxides and unburnt hydrocarbons in vehicle exhaust gases can react in prolonged strong sunlight to form ozone and other eye-smarting chemicals, known as oxidants because of their strong oxidising effect. Nitrogen oxide plays a part in the formation of ozone, and ozone is in turn involved in the conversion of sulphur and nitrogen oxides to acids. The formation of man-made ozone has increased enormously with the rising levels of nitrogen oxides in the atmosphere.

Until recently, relatively little attention was paid to the role of ozone in air pollution, beyond its well-known and well-documented effects during photochemical smogs in urban areas. But ozone is now recognised as a major factor in the formation of acid pollution, and even as the cause of damage wrongly blamed on acid pollution. There is conclusive evidence that man-made ozone damages crops and plants (including trees), and some suggestion that it may damage human health and property as well. Many West German scientists argue that ozone — acting with or without acid rain — is the real cause of damage to West German forests and crops. (This low-altitude man-made ozone should not be confused with the natural ozone in the stratosphere, which forms a thin, protective layer 7-16 km (4.5-10 miles) above the earth's surface, preventing damaging ultra-violet radiation from reaching the surface.)

Scientists at Imperial College, London have been studying the effects of ozone on crops since 1977, and believe that it can reduce yields by 10-20% in sensitive species. Laboratory findings have been supported by evidence of crop damage in open fields. The team say that ozone concentrations sufficient to damage crops can be expected to occur intermittently over most of the British Isles, even in years when hours of sunshine are low. [12]

The linearity debate. One of the most contentious issues in the acid pollution debate is the question of 'linearity'. Is there a linear relationship between emissions and deposition? In other words, will a given reduction in emissions result in a proportional reduction in deposition? Opponents of action to curb acid pollution often argue that the formation of acid depends so much on weather conditions that emissions do not always convert to acids, and so reducing emissions may not reduce acid pollution proportionately. In its 1982/83 annual report, Britain's Central Electricity Generating Board concluded that "the acidity of rain in Europe cannot be expected to respond proportionately to changes in the amount of sulphur dioxide emitted".

The earliest research into acid deposition tended to assume a linear relationship. Then evidence emerged in the early 1980s that the amount of acid formed depended more on photochemical oxidants such as ozone than on SO_2 levels. The suggestion was that once these oxidants had been exhausted, no more acid could be formed. Hence it could be logically argued that a reduction in levels of NO_x and hydrocarbons (which create the oxidants) would have more effect on reducing acid pollution than a reduction in SO_2 levels. [13] In its 1983 review of the chemistry of acid pollution, the US National Research Council (NRC) concluded that there was no evidence to support a non-linear relationship in northeastern North America, when emission and deposition figures were averaged out over a year and over the entire area. "If the emissions of sulphur dioxide from all sources in this region were reduced by the same fraction, the result would be a corresponding fractional reduction in deposition." [14] On the other hand, the NRC pointed out that in Europe, where precipitation monitoring programmes had been in existence for much longer, there was some direct evidence of a non-linear relationship. For example, monitoring between 1960 and 1975 found constant or declining rates of sulphate deposition despite the fact that there were significant increases in SO_2 emissions in the same period. But there were some doubts about the sampling and the analytical techniques used.

Further evidence of linearity came in a 1984 study by the US Environmental Defense Fund (EDF) in the southwestern United States. Using information from southwestern copper smelters, and data from the monitoring stations of the National Acid Deposition Program, which makes daily measurements of pollution, the EDF was able to determine fluctuations in acid deposition. These were then compared with smelter emission figures. Acid pollution was worst on days of heavy smelter activity, and reduced on days when the smelters were operating at lower production levels. The report concludes: "The variations in sulphur concentrations at all monitoring stations are consistent with the variations in smelter emissions". [15]

The evidence on this question is still patchy and inconclusive, but average figures of emissions and deposition taken over a period of time and over large regions suggest a strong likelihood of a linear relationship.

3. Pollution

The environmental effects of acid deposition depend on whether it is dry or wet, and on the level of contact it has with plants, watercourses and buildings. The US National Research Council identifies three levels of receptors of acid pollution:

- *primary* receptors experience direct contact with atmospheric pollutants, e.g. the outer surfaces of buildings, trees and plants;
- *secondary* receptors experience contact with pollutants only after they have been in contact with other materials, e.g. the inner foliage of plants or the soil beneath vegetation;
- *tertiary* receptors are indirectly affected by pollutants, e.g. subsoil, bedrock, and watercourses and lakes that receive most of their water from runoff.

Dry deposition has several direct effects on the environment. It attacks and corrodes buildings, metals, stone and even leather, paper and textiles. It is deposited on forests and farmland, affecting plant growth and crop yields. It mixes with fog and dust to create smogs that can cause respiratory problems among susceptible people and animals.

Wet deposition has both direct and indirect effects. It increases the acidity of lakes and rivers, which is made worse by the inflow of acids and metals from nearby soils. The effects vary depending on the volume of deposition and the inherent sensitivity of the soils and waters. Aquatic species die, making the lakes and rivers too barren to support fish life. Wet deposition can transport metals such as aluminium, cadmium and mercury into soil water, groundwater, lakes and streams, depleting the stock of nutrients in the soils and weakening plants. It has been implicated in reduced crop yields and further corrodes buildings and structures. More controversially, it has been alleged to aggravate heart and lung diseases in humans — exactly how is still a matter of debate.

Soil acidification. Soil is the key element in determining how acid deposition affects forests, lakes and watercourses. Soil that is deep and rich in lime or other alkaline substances has a high neutralising capacity, i.e. an ability to neutralise the acids in the water seeping through it, and so can offset the effects of acid deposition. By contrast, thin sandy soil or granitic terrain has little neutralising capacity, and acid deposition will tend to run off into rivers and lakes with most of its acid content intact.

The natural acidity of soils is determined by factors such as geology, soil type and vegetation. The acid content of naturally acidic soils can come from the carbonic acid naturally present in rainfall, from the nitrification of natural sources of nitrogen, or from the oxidation of iron sulphides. Carbonic acid is also produced by microbial activity in soils. When plants and animals decompose into humus, carbon dioxide is formed, which reacts with moisture to produce carbonic acid. Hydrogen ions are then released and the soil temporarily becomes slightly more acidic.

In a natural ecosystem (such as a forest), there is a cycling of nutrients and hydrogen ions between the soil and the vegetation. Plants take up nutrients like calcium, potassium, sodium and magnesium from the soil, where these exist in the form of positively charged ions *(cations)*. To maintain the ionic balance in the soil and roots, plants release other cations (mainly hydrogen ions) to the soil, which can lead to natural acidification.

But when a tree dies and decomposes, the nutrients previously absorbed are released into the soil, neutralising the hydrogen ions. In deciduous woods, leaf fall annually transfers neutralising cations to the soil surface, compensating for those washed down the soil profile by percolating rain. The addition of large quantities of hydrogen ions will upset this natural cycle, leading to soil acidification and leakage of nutrients faster than they can be replaced by the natural weathering of the rocks and deeper soil layers.

Man-made soil acidification comes from several sources. Modern agricultural and forestry techniques produce an imbalance between the production and consumption of hydrogen ions in the ground. Until 20-30 years ago, many commercial fertilisers were formulated in a way which helped counteract any increases in acidity. Today many commercial fertilisers are ammonium-based, releasing hydrogen ions, and so promoting acidification.

Agricultural intensification — particularly in Western Europe — may also have an effect by removing plant mass from the ground. If dead leaves and stalks are left to rot naturally, they return nutrients to the soil and neutralise the hydrogen ions in the soil. The more plant mass is removed from the ground, the less the soil will be able to neutralise the hydrogen ions brought by air pollution and inflowing water.

The rate at which soils acidify depends on the rate at which the basic cation nutrients in soil (e.g. calcium, magnesium, potassium and sodium) are replaced by hydrogen ions in the soil water. As acid rain increases the input of hydrogen ions, so the rate of cation exchange increases. Once displaced, the cations can be leached down through and out of the soil. A sign of increasing soil and ground acidification is a rising level of cation content in the groundwater.

Neutralising. The acidification of soil can be delayed or prevented altogether by protective neutralising systems. While most soils have enough neutralising capacity to offset the effects of acid rain, the chemical properties and stability of soils and soil ecosystems vary considerably. Their susceptibility to acidification depends on several factors: the type of bedrock, the kind of soil, the size of soil particles, and how the land is used.

Soils have two main neutralising systems: ion exchange, and chemical weathering. The rate of ion exchange depends on the supply of cations. The fewer the cations, the less the neutralising ability. In medium or rich soils, acidification takes longer because the exchange of ions has to work its way down through many layers before the soil is so acidified that new hydrogen ions will penetrate the ground directly and reach the groundwater.

Weathering (the breaking down of rocks and soils by natural weather conditions) is a much slower neutralising process. Generally speaking, the more easy-weathering the material is, the richer it is in basic chemical constituents, the faster is the release of neutralising metallic cations, and the stronger its resistance to acidification. Bedrocks are influential because they are the origin of soils. Lime-rich rocks such as limestone and marble weather relatively easily, but hard granite or gneiss bedrocks are more resistant.

The process by which soils can neutralise acid deposition is also known as *buffering*, because it keeps the soil at roughly the same pH irrespective of fluctuations of acid input. But just as a train can hit the buffers too fast to be stopped, so the natural buffering capacity of the soil can eventually be exhausted.

Most of the research on the sensitivity of soils to acid has been carried out in Europe and North America. Much of Scandinavia, parts of Scotland, and the Rocky Mountains and northeast United States, for example, have old, lime-poor bedrocks with little surface soil. Elsewhere in Europe, the rocks are often high in lime, making them far more able to neutralise acid deposition or acids formed in the ground.

In general, areas covered with ice in the last Ice Age (10-15,000 years ago) have relatively young soils, and are less able to buffer continued acid pollution. In older soils, natural weathering has been going on much longer. The laterite soils of the tropics are closer to the end of their weathering process; hardly any nutrient cations remain. Most of the nutrients in circulation in a tropical forest ecosystem are locked up in the vegetation, and dissipated if plants are destroyed. Soils in large areas of the Third World will be rapidly susceptible to acidification. The most sensitive soils are the cambisols found widely in eastern North America, Europe and China, and the laterites of South America, Africa and southern Asia.

Groundwater. Water reaching the soil surface can evaporate, run off the surface, or penetrate the soil. Rock, other impermeable ground material and even sloping ground can cause the water to run off the surface without penetrating far. Losses from evaporation are small in cooler temperate regions, so most of the deposition moves through the soil to form groundwater.

Groundwater can be acidified when the water is not sufficiently neutralised as it runs through the soil layers. The neutralisation of the soil water and, eventually, of groundwater depends on the alkalinity of the soil or rocks and how long the soil particles or rocks are in contact with the percolating water: the 'turnover time'. The finer the material, the longer the turnover time and the better the chances of neutralisation before the groundwater reaches lakes and watercourses.

Lakes and rivers. Rainwater enters watercourses either directly (by falling on the surface) or indirectly (by draining off or through neighbouring soils). Several factors determine the susceptibility of lakes and watercourses to acidification:

- *The neutralising capacity of surrounding soils.* Most Swedish lakes are in areas with granite and gneiss rocks that do not weather easily and with soils that are low in lime. Hence they have low neutralising capacity. By contrast, lakes in parts of central and south central Sweden sit on lime-rich bedrock or soils, containing calcium carbonate and rich stocks of bicarbonate ions, that act as a reserve to buffer excess acid.

- *The extent and volume of surface runoff.* The heavier the rain and the more impermeable the ground, the greater the volume of runoff, and the less time the water will have to permeate the ground and be neutralised. One of the most dramatic sources of acid runoff in northern Europe and North America is the spring snow-melt. Thaws of deep snow can release a sudden and massive volume of water containing accumulated acid. Rainstorms following extended dry periods can wash off dry-deposited sulphates (and sulphide materials that may have been oxidised to sulphates during the dry spell) with similarly traumatic effects. Acid surges like these can overwhelm the neutralising capacity of a lake.
- *The size of the catchment area.* The smaller the area, the shorter the time before runoff water reaches the lake and the less time there is for the water to be neutralised.
- *Location in water system.* Lakes at high altitudes are closer to the sources of streams, so the water emptying into them will have had less time to be neutralised.
- *Soil humus content.* Humus can both absorb acid, making the lake more alkaline, and produce hydrogen ions, making the lake more acid.

There are three stages in the acidification of surface water.

In the first stage, bicarbonate ions neutralise acids by reacting with hydrogen ions to produce carbon dioxide and water. Lakes have varying concentrations of negatively-charged bicarbonate ions (HCO_3), the levels depending largely on the surrounding bedrock and soil.

Where the soils have a high neutralising capacity, few hydrogen ions will reach the lake, which will have high and stable levels of buffering bicarbonate ions. But lakes and watercourses in poorly buffered areas must use — and may exhaust — their bicarbonate ions. The natural formation of new bicarbonates (via carbonic acid from the air, weathering from the land, and decomposition of water plants) can be overwhelmed by continuous inputs of acid.

As long as the bicarbonate content is maintained at a critical minimum level, the pH value of the water will remain stable, and plants, animals and microorganisms will be unaffected. But a lake or watercourse subject to major acid inputs will be vulnerable.

In the second stage, the bicarbonate content drops below the critical level, and large influxes of hydrogen ions can no longer be neutralised. The pH value becomes unstable and begins to go down faster than before. Acid surges can drastically upset the delicate balance that remains. A sudden release of huge amounts of acidic water into the lake or watercourse

— after the first thaw of spring in the northern hemisphere, or when heavy rains follow a period of drought — can be deadly, especially if it occurs when the organisms are at the most sensitive part of their life-cycle (for fish, when they are young, i.e. at the fry stage).

The third stage comes when the pH value stabilises around 4.5, regardless of new influxes of hydrogen ions. Almost all the original life — including snails, crustaceans and many insects — is eliminated, fish disappear, and a small number of resilient animal and plant species predominate. An entirely new ecosystem emerges. The water becomes abnormally clear — visibility can increase from 4-5 metres (12-15 feet) to anything from 15 to 20 metres (50-65 feet) because the tiny plants that normally float in the surface waters, and the organic matter normally suspended in the lake, are both greatly reduced in density.

The rise in hydrogen ion content triggers a sequence of other, often more damaging, chemical changes. For example, the aluminium content of surface water may change. The aluminium content even of unaffected water can be quite high, especially if the water is rich in humus. One effect of soil acidification can be the release of aluminium ions, which function as a transport medium for hydrogen ions, to nearby groundwater and surface water.

Natural sources of acidity — carbonic acid in rain, and organic acids from humus decomposition — can contribute to a background acidity of pH 5 in lakes, but are not by themselves enough to account for recent surges in acidity in many parts of Europe and North America. Some kinds of land use — such as afforestation — can also promote acidity in watercourses. The most acid rivers in Wales, for example, are those surrounded by planted coniferous forests. Forest canopies can accumulate dry-deposited acids which can then be washed off into rivers and lakes. Tree harvesting may be another factor: if a stump and roots are left behind, decomposition helps reduce the amount of hydrogen ions in the soil; if everything is removed, so is this additional source of neutralising capacity.

Mobile metals. Acidity in water can release the metals in soils (including aluminium, cadmium, mercury, lead and arsenic), which go on to contaminate groundwater and surface water. Except for aluminium, which is one of the commonest elements (making up 8.1% of the earth's crust), most of these metals are present in soil only in small quantities, and hence are known as trace elements.

Aluminium plays a key role in several chemical and biological processes provoked by an excess of sulphur and nitrogen compounds. Aluminium is normally tied to soil particles or to humus substances in water, and causes no harm to living organisms as long as it is immobile. But in well weathered soils with a high input of hydrogen ions, aluminium ions can be released and washed deeper down into the soil, eventually reaching the groundwater.

Aluminium damages the finer root filaments of plants and impedes the uptake of nutrients and water. The dissolved aluminium also interferes with the ability of plants to assimilate phosphorus (a plant nutrient), which is tied up by the free aluminium into the almost insoluble aluminium phosphate. The input of phosphate, essential to plant growth in lakes, is therefore reduced and the whole basis of the ecosystem is affected.

Aluminium is also directly toxic to animals, mainly fish. The chemistry of aluminium in freshwater is complex and poorly understood, but it is now widely thought to play a key role (but not the only role) in fish deaths, by damaging their gills. High levels of aluminium hydroxide in surface water usually lead to mass death of fish. Birds with high aluminium levels in their metabolism may lay eggs without shells, or with shells that are too soft for the egg to survive.

There is still some doubt about the toxic effects of aluminium on humans. Some kidney patients have apparently suffered speech and brain damage from aluminium-contaminated water used in dialysis. Humans can absorb aluminium directly through drinking water from acidified areas. There may also be some uptake of aluminium in grain and other plants cultivated on acidified ploughed land.

Natural *cadmium* levels are raised by cadmium released by industrial activity, including fossil fuel combustion and metal smelting, and by the use of commercial fertilisers containing cadmium. Acidification releases soil cadmium into water and causes plants to take it up more readily. It can reach the human body through drinking water, air and food, and tends to concentrate mainly in the kidneys. Some groups of people in heavily industrialised countries already have such high concentrations of cadmium in their kidneys that any increase in the load risks severe illness.

Recent research in Sweden has revealed unexpectedly (and disturbingly) high concentrations of *mercury* in fish and freshwater in acidified regions. The source of this mercury is uncertain, but much may be airborne and originate in coal burning. In soil, and in the bottom sediments of acidified lakes, it is converted to methyl mercury, in which form it is more easily accessible to plants and animals. The concentration of methyl mercury in fish is thus increased by acidification. The accumulation of mercury grows as it moves further up the food chain.

Chapter 2

Acid damage

Acid pollution can damage trees, plants and crops, can lead to a decline in freshwater animal and plant life, may pose a threat to human health, and can corrode stone and metal — both above and below ground. But the mechanisms by which this damage occurs, and the relative contribution of acid pollution and other natural or man-made factors, are still unclear.

Forests

Forests are not just stands of trees, but complex ecosystems — a chain of interdependent processes involving trees, soil, water, the air, climate and other living organisms.

Forests are natural air filters; they enrich the air with humidity and regulate the local climate; and they control ground and surface water by collecting, storing, filtering and distributing it and regulating the water table. Forests bind soil and prevent erosion; they prevent landslides, rockfalls and avalanches, provide effective windbreaks, control the passage of air into otherwise vulnerable areas such as valley basins, and provide protection against frost.

Forests are also a major economic resource. In West Germany, for example, forest timber is valued at $45-62 billion. The Union of German Forest Owners Associations estimates that present losses as a result of forest dieback total more than $300 million per year.

The first signs of alleged forest damage in Sweden in 1972 were largely discounted at the time, and a short period of dieback followed by recovery in southern Sweden in 1973-76 was attributed by Swedish botanists to climatic stress. But within the last three years there has been mounting evidence of massive damage to trees across much of Europe and North America. More than five million hectares (12 million acres) of forest have been affected to varying degrees in just four European countries: West Germany, Poland, Yugoslavia and Czechoslovakia. Forest damage has also been found in East Germany, the Netherlands, Switzerland, France, Austria, Sweden and the United States, and is suspected in several other countries.

The links between this dieback and acid pollution are unclear. A 1983 European Commission report argued that there was "no unequivocal evidence" of acid deposition having affected the growth of trees in EEC member states. [16] But in March of the same year, a council of environmental advisors to the West German government noted that "all serious attempts to explain [forest damage] concluded that air pollutants, either alone or in combination with other pollutants and/or aspects [climate, location, pests, forest cultivation influences], play a decisive part in both causing the damage and determining its extent". [17]

West Germany was spurred to action on acid pollution in 1982 partly by the spectre of dying forests. The damage — a progressive loss of needles and changed growth patterns in fir and spruce — is clearly visible, but many scientists argue that other factors beside air pollution have been involved. The damage is most obvious in trees at higher altitudes and in exposed positions, perhaps because the climate there is more severe and because pollution can be trapped below 'inversions' in the atmosphere, moving without much mixing to make contact with valley sides and hilltops.

In some places damage appears to have been brought on by a harsh winter or a summer of drought. Many southern and central German forests are ecologically fragile and their soils chemically deficient. Poor forest management has contributed to soil degradation and perhaps to acidification. Climatic stress (such as drought, frost, strong winds and storms), slow changes in the soil and attack by pests and diseases have all been suggested as causative factors in dieback. Pests and diseases probably have an effect when trees have already been weakened by other factors.

One theory holds that West German forest dieback is partly a result of the indiscriminate planting of trees at the turn of the century. Trees planted on unsuitable soils are among the most seriously damaged today. But the apparently widespread and rapid increase in damage in recent years also suggests that the forests may finally be showing the effects of a cumulative weakening that has been aggravated by air pollution. Examination of annual growth rings suggests that affected trees began to grow more slowly as much as 20 years before the symptoms of damage appeared.

The problems of diagnosis are well illustrated by a 1984 survey by Britain's Forestry Commission (which both manages state forests and regulates private forestry). The study concluded that the browning of pine needles and death of shoots in northern England was probably caused by cold and windy winter weather rather than acid pollution. The survey, the first of its kind in Britain, found that 6% of spruces and 20% of Scots pines had "an appreciable degree of crown thinning ...well within the usual range of our experience". While much of the damage to Scots pine was put down to insects and fungi, pines and spruce in higher rainfall zones did have a lower crown density, which the Forestry Commission conceded could have been caused by acid pollution.

Effects on growth. The links between acid deposition and forest damage are as complex as the forest ecosystem itself. West German scientists studying forest dieback have outlined theories that involve as many as 160 different possible causative factors.

The susceptibility of forests to acid damage depends on a number of factors, including the species of tree (deciduous trees are less susceptible than evergreens, possibly because they shed their leaves annually), the neutralising capacity and depth of the soil, local climate, and the position and altitude of forests (trees at higher altitudes or in enclosed valleys may receive more rain than those in lowlands, and may sometimes be enveloped in acid mist).

Trees are more directly exposed to the influence of wind than other plants. The particles, gases and acids they filter or screen from the air end up on their leaves or needles, their bark or on the ground. Evergreens are more efficient at filtering than deciduous trees but this efficiency makes them more vulnerable to pollution. Because deciduous trees shed their leaves every year, the cycle of air pollution damage is temporarily broken.

Damage to trees takes the form of visible damage to leaves and needles, a decline in growth, and loss of resistance to disease and to other stresses such as storms or drought. The symptoms include (in conifers) a yellowing and loss of needles, stunted growth, thinning out of tree tops, soft-rot and root damage, and (in deciduous trees) leaf discolouration and misshaping, early leaf fall, death of tree tops, damage to bark and lack of natural regrowth. These symptoms occur in varying degrees of intensity and in different combinations.

Air pollution mainly affects trees directly through the foliage. SO_2, ozone and perhaps NO_x can all affect the living tissues, entering leaves through the stomata (leaf pores). Laboratory experiments show that each pollutant can aggravate the effects of others. Many trees are particularly sensitive to ozone, and in the laboratory show damage at concentrations like those now being experienced in the field in southern Sweden and parts of West Germany. Air pollutants almost certainly increase the permeability of cell membranes, making them more likely to leak out calcium and magnesium, which can be washed away in rain (especially if the rain is acid), depriving the tissues of essential nutrients.

Ozone and SO_2 may also damage the green chlorophyll pigment essential for photosynthesis, which uses sunlight to convert water, carbon dioxide, nitrates and minerals into oxygen, carbohydrates and proteins. The loss of magnesium may account for the yellowing of spruce needles commonly seen in West Germany, since magnesium plays a central part in the structure of the chlorophyll molecule, as iron does in haeomoglobin.

Jiri Polacek

Forest dieback, Czechoslovakia. Trees are more exposed to wind than any other plants. Air pollution damage is often obvious in trees at higher altitudes and on exposed slopes, but distinguishing air pollution damage from other factors is difficult.

The loss of magnesium and calcium from the leaves causes the roots to work overtime to replace these crucial nutrients, and the resulting transfer of these nutrients from the soil increases the hydrogen:calcium ratio in the soil, and hence the acidity.

Some pollutants are swept out of the air by the leaves and branches of tree canopies. The amount of acid deposited on the soil under trees can be several times greater than on adjacent open ground. Sulphur deposition levels near the edges of woodlands in Sweden have been shown to be approximately twice those in the general forest area. This is clearly liable to aggravate forest damage and the throughput of acidity to the soil.

Acid pollution may also affect the microorganisms (bacteria, fungi and algae) that trees depend on to break down organic matter into nutrients. Some bacteria are nitrogen-fixing, thereby helping plants — including trees — to absorb ammonium and nitrate ions via the root system.

Increasing acidity in soil is likely to cause the release of aluminium, an important constituent of soil minerals like clays. In the free inorganic form, aluminium is toxic to plant roots and can lock up phosphate in the soil, thereby depriving the tree of this essential nutrient for growth.

The deposit of nitrate (from NO_x) and ammonium (also from air pollutants) has another effect. They are not washed through the soil by drainage water but, because they are important nutrients and stimulate growth, they are taken up by plants. This very stimulus can add to the stress on the plant, pressing it into extra growth activity and increasing the demand for mineral nutrients.

In early 1985, Dr Bengt Nihlgärd of Sweden's University of Lund published a paper suggesting that the build-up of nitrogen in soils and plants — as a direct result of atmospheric deposition — could be an additional explanation of forest dieback in Europe. Nitrogen in the form of ammonium or nitrate is an important plant nutrient, but most plants have adapted through evolution to be able to exist with very low levels of nitrogen. The recent increase of available nitrogen in precipitation and the air has caused nitrogen 'over-saturation' in northern European temperate forests. Tree growth has accelerated, and trees have formed large cells that are easily attacked by wind, drought and pests.

The surplus nitrogen is transformed into ammonium, and this is usually accompanied by oxidation and the release of hydrogen ions or organic acids. Soluble carbohydrates are consumed, non-protein nitrogen compounds and hydrogen ions are stored in leaves, root growth decreases and frost resistance is reduced. The result may be long-term tree damage. |18|

Plants and crops

Plants and crops can be damaged by pollutants both acutely (through short periods of high concentrations) and chronically (through impaired growth due to prolonged exposure at lower concentrations).

Distinguishing damage caused by pollutants from damage caused by climate, soil, pests or diseases is difficult. Most of the existing studies of the effects of acid deposition on plants have been carried out with SO_2, ozone or a combination of the two, and almost all of these studies involved laboratory experiments concerned more with the effects of long-term exposure than with short-term episodic exposure. But high peak concentrations of pollution are thought to be more critical than long-term exposure, according to the European Commission. |19|

Studies to date show that the combined effect of two or three pollutants acting together (synergistically) is much more harmful than each pollutant acting alone. Laboratory tests have shown that SO_2 on its own can cause visible damage to plants in as little as three hours, but at concentrations unlikely to be found in most rural areas. In a 1981 Organisation for Economic Cooperation and Development (OECD) study, the total crop damage from SO_2 alone in 11 European countries was estimated at $500 million per year. [20]

Nitrogen oxides are thought to be less of a cause of direct acute damage than other pollutants because, although NO_x concentrations can reach high levels in rural areas, they are less easily absorbed by plants. But in lower concentrations, and acting synergistically with other gases, NO_x may be significant. Laboratory tests suggest that some vegetative growth can be reduced by up to 35% in atmospheres containing mixtures of SO_2 and NO_x.

NO_x also plays a role in the formation of ground level ozone, a key element in pollution damage to crops and plants. One important difference between ozone and SO_2 is that natural background concentrations of ozone are already perilously close to the levels that can damage plants. Even a moderate increase in ozone can be enough to make it dangerous.

Ozone damages plants by attacking leaf cells, destroying chlorophyll and thereby lowering the rate of photosynthesis. The outer cells remain intact, giving the impression that the leaves are healthy. The damage eventually becomes visible as dark coloured spots or discoloured areas on the leaf surface. Tobacco plants show early visible signs of damage. Until the late 1950s this damage was called 'weather fleck', now it is recognised as ozone damage. [21]

There has been conclusive evidence over the past 20 years of plant and crop damage from ozone during high summer concentrations in rural areas of the United States. The most sensitive species are potatoes, tobacco, grapes, dwarf beans and radishes, all of which can experience visible leaf damage. Growth has also been affected in soya bean, winter/spring wheat and clover.

Ozone has killed pine trees in the San Bernardino National Forest east of Los Angeles, a city notorious for its smog. As early as 1969 it was revealed that 1.3 million Ponderosa and Jeffrey pines had been affected. In areas where the highest ozone doses were measured, the timber yield of 30-year old pines declined by 83%. Weakened trees were later attacked by bark beetles. Similar damage appeared in the Appalachian mountains of the eastern United States. However, it is not possible to say with certainty that ozone rather than a combination of pollutants was responsible in these cases.

In 1980, the National Crop Loss Assessment Network investigated crop losses in the US from ozone, SO_2 and NO_x. By studying the effect of ozone on the yield of several important crop species, it concluded that substantially greater yields of food crops would be available if ozone concentrations could be reduced from existing levels to 'natural' levels (50 microgrammes per cubic metre). A panel of scientists appointed in 1982 by the Presidential Science Advisor supported the view that ozone caused crop damage.

Lakes, rivers and fish

The effect of acid deposition on lakes is gradual, quiet and insidious. There are rarely any rotting corpses of fish or other visual evidence. "There is no muss, there is no fuss, there is no smell", observed Dr Harold Harvey of the University of Toronto. "The fish quietly go extinct... They simply fail to reproduce and become less and less abundant, and older and older, until they die out."

Acid deposition has caused declines in populations of fish, aquatic plant life and microorganisms in Canada, Sweden, Norway and Scotland. Surface water acidification has been reported from Belgium, the Netherlands, Denmark and West Germany.

A survey of one Canadian lake — Lumsden Lake in the La Cloche Mountains near Killarney, Ontario — has revealed a clear timetable of change. In the 1950s the lake had eight species of fish. In 1960 two of the species were reported for the last time. In 1960-65 the sport fishery failed. In 1967, two more species were reported for the last time, and three more in 1969. By 1971 the one remaining species was very rare. All the species are now extinct. [22]

Changes in the biology of lakes provided one of the first clues to the effects of acid pollution. Changes were noticed as early as the 1920s, but it was only in the 1950s and 1960s that the link with pollution was made. By studying the shells of dead algae in lake sediments, Swedish researchers found that the pH of lakes in Sweden had fallen from about 7.0 at the end of the last Ice Age 15,000 years ago to about 6.0 in 1949-1950, when a more rapid decline began. Lakes have since dipped below pH 5.

A survey of 15 lakes in western Sweden in the 1930s and 1940s returned pH levels of 8.0-6.5; by 1971, the pH had fallen to 4.5. [23] More than a fifth of Sweden's 85,000 medium to large lakes are now acidified. About 4,000 lakes are seriously acidified and have suffered major damage to their biology, and in about 9,000 lakes — mainly in southern and central Sweden — fish stocks have been affected to varying degrees.

The best researched effect of the acidification of inland waters is that on fish, which can die of aluminium poisoning even in lakes with moderate pH values. Aluminium in soluble inorganic form is thought to be especially toxic to fish. Almost as soon as fish hatch, the aluminium causes mucus clogging in the gills, which in turn reduces ion exchange across the membrane of the gills. Ion exchange is essential to the maintenance of the salt balance in the blood of fish. Reduced blood salts affect respiration, metabolism and cell volume, which can result in death. Acid in water can also kill fish eggs. Salmonid species, such as salmon and trout, are particularly sensitive to acidification. Fish can apparently adapt to a gradual lowering of pH, within limits, but rapid change, or acid surges following snow-melts, can lead to a permanent decline in fish populations.

pH	*Effect*
6.5	Continued exposure results in significant reductions in egg hatchability and growth in brook trout.
6.0	With high CO_2 concentrations, certain trout species can be adversely affected.
5.5-6.0	Rainbow trout do not occur. Small populations of relatively few fish species found. Molluscs rare.
5.5	Declines in salmon fisheries can be expected.
5.0-5.5	Restricted fish populations, but not lethal unless CO_2 is high. May be lethal to eggs and larvae, and to some mayflies. Diversity of bacterial species reduced.
5.0	Tolerable lower limit for most fish.
4.5-5.0	No viable fishery can be maintained. Lethal to eggs and fry of salmon species.
4.0-4.5	Fish population limited: few species survive. Flora restricted.

Figure 3. Biological effects of acid waters in Canada. Source: Ministry of the Environment, Ontario.

In 1980, the Ontario Ministry of the Environment reported that 140 acidified lakes in the province had no fish at all, and a further 48,500 lakes would not be able to tolerate extended acid inputs. At current rates of deposition, all the fish in these lakes too will be gone in 10 years. Lake Donald, once one of Ontario's best bass and trout lakes, had lost all its fish by 1950. In 1973 it recorded a pH of 3.8.

In Norway's four southernmost counties, fish stocks have been halved since 1940. Lakes covering an area of more than 13,000 sq km (5,000 sq miles) contain no fish, and fish stocks have been reduced in a further 20,000 sq km (7,700 sq miles). In the early 1970s, more than half the lakes above 600 metres (2,000 feet) in New York's Adirondack mountains had pH values below 5.

The critical pH level for most aquatic species is 6. When the pH falls below this level, the number of species, and the population of algae, animal plankton, aquatic insects, insect larvae, and sensitive fish (such as salmon, roach and minnow), declines. Below 5.5, the number of snails and microscopic plant species is reduced. Below 5.2, snails disappear. Below 5.0, many microscopic animal species disappear, and even the more tolerant species become rare. Acidification affects the growth and productivity of many aquatic plant species, slows the bacterial decomposition of dead matter, and reduces the sources of food for birds and mammals that depend on freshwater ecosystems.

Human health

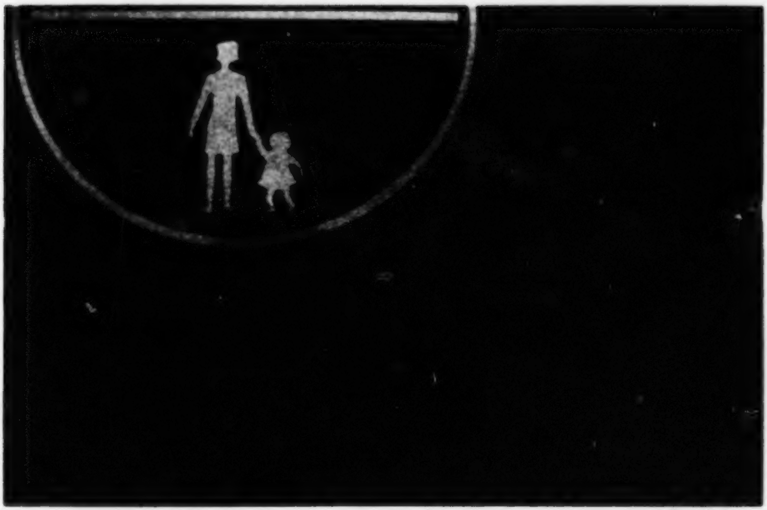
In London, Tokyo, Mexico City, São Paulo and Beijing, millions of people have physically suffered the effects of acid-related pollution. Following the London smog of 1952, 4,000 people died from heart or lung ailments made worse by the smog (caused by smoke and SO_2), and many more fell ill. The very young, the elderly and those with heart and lung disorders are particularly vulnerable. The effect of one kind of pollutant may often reinforce the effects of others, making it difficult to identify the most damaging substance.

The links between acid pollution and human illness are generally fuzzy, and frequently subject to conjecture and even exaggeration. New warnings emerge regularly, linking pollution to everything from headaches to cancer and senile dementia. In some cases the evidence is strong, in others circumstantial. The medical data is often patchy and very little is known for certain, a reflection partly of the general uncertainties about the environmental effects of acid pollution, and partly of the many other variables (such as social and economic status, diet, and quality of health care).

The Katowice region of Poland offers a good example of the circumstantial evidence linking health problems to acid pollution. The region covers 2% of Poland's land area; holds 10% of its population; produces 31% of its coke, 32% of its electricity, 52% of its steel, and 98% of its coal; and extracts and processes 100% of its zinc and lead ores. Some of the cities in the region get more than one kilogram per square metre (about one pound per five square feet) per year of industrial particle fallout. Many of the houses are built right up against the factories and smelters, and garden soils contain as much as 16 times the prescribed limits of cadmium and 44 times the lead limits.

The people of the Katowice region suffer 15% more circulation disease than the national average, 30% more tumours and 47% more respiratory diseases. Of Poland's 102 schools for disabled and deformed children, 54 are in Katowice. [24] There is no proof that acid pollution is the cause of any or all of these health problems, but it seems likely.

Acid pollution may pose a threat to health in three ways: in the short-term through breathing heavily polluted air (as in the London smog); a long-term deterioration through constantly breathing lower levels of polluted air; and indirectly by exposure to heavy metals or aluminium released into soils and water as a result of acidification, the accumulation



Otto Freiburg

Controversy rages over whether or not acid pollution affects human health. Distinguishing the effects of different pollutants is difficult. The evidence so far suggests that the very young, the elderly and people with heart and lung disorders are more vulnerable to the effects of air pollution.

of metals in the aquatic food chain, or heavy metals dissolved in acidic water supplied through lead or copper piping.

SO_2 is a relatively non-toxic gas by comparison with carbon monoxide or nitrogen oxides, but high concentrations have been known to cause respiratory problems in humans. Other pollutants — sulphates, nitrates and ozone (and other oxidants), polycyclic aromatic hydrocarbons, carbon monoxide, aluminium, arsenic, copper, and heavy metals such as lead, cadmium, and mercury — have varying (proven and supposed) effects on health.

The World Health Organization recommends a maximum daily average of atmospheric SO_2 of 100-150 micrograms per cubic metre. Yet Stockholm, a relatively 'clean' European capital in terms of air pollution, experienced maximum daily averages of 250 micrograms in 1980, a level at which there is a deterioration in the conditions of patients with respiratory diseases, according to the Swedish Ministry of Agriculture.

Ailments and diseases that have been linked (correctly or incorrectly) with acid pollution include chronic respiratory diseases (such as bronchitis and asthma); cancer of the lungs, kidneys and blood; damage to the central nervous system; brain damage; mental retardation, and behavioural disorders.

Friends of the Earth US quotes a 1982 US Congressional Report which indicated that 51,000 people died in North America in 1980 from illnesses caused by airborne sulphur compounds; the victims were people who already suffered from respiratory diseases. The US Council on Environmental Quality estimated that health related problems directly attributable to acid precipitation were costing the US $2 billion annually in the late 1970s.

Unfortunately for medical researchers, people breathe polluted air, not individual pollutants. So it is difficult to disentangle the effects on health of sulphur dioxide, ozone, smoke, lead and a dozen other contaminants. But there is growing evidence that acidity plays an important role in the health damage of polluted air.

Corrosion

The corrosion of historic buildings and monuments is nothing new. Soft building stones have always been eroded to some extent by the combined effects of wind and unpolluted rain. The difference today is the degree of the problem.

Theoretically, almost every building either in, or downwind of, a major urban or industrial centre may be at risk from the corrosive effects of acid deposition, dry or wet, and there is conclusive evidence that the rate of corrosion has increased dramatically in many urban areas. Buildings and structures which have stood largely undamaged for hundreds, even thousands of years, have recently begun to be affected. A Greek specialist on acid corrosion, T.N. Skoulikidis, has estimated that the deterioration of Athenian monuments in the past 20-25 years, as a result of pollution, has been greater than in the previous 2,400 years.

Most of the corrosion of city buildings and monuments is the result of the dry deposition of SO_2 and sulphate particles, and is mainly due to high and localised urban concentrations of pollutants. When sulphur pollutants fall on the surface of sandstone or limestone, for instance, they react with the calcium carbonate in the stone to form calcium sulphate (gypsum). This causes flaking that can then be washed away by rainwater, exposing more stone to corrosion, and so on.

The corrosive effects of wet deposition are less certain. Acid rain can deposit ions on building surfaces that stimulate corrosion. On the other hand, the rain also washes off the sulphates deposited on the surfaces during dry periods.

The rate of material corrosion is affected by several factors. The *relative reactivity* of the material to acidity is critical: stone and masonry that

Material	*Type of impact*	*Principal air pollutants*	*Other environmental factors*
Metals	Corrosion, tarnishing	Sulphur oxides, acid gases	Moisture, air, particles, salt
Building stone	Surface erosion soiling, black crust formation	Ditto	Mechanical erosion, salt, particles, moisture, CO_2, temperature fluctuations, vibration, microorganisms
Ceramics and glass	Surface erosion, surface crust formation	Acid gases esp. fluoride-containing	Moisture
Paints	Surface erosion, discolouration, soiling	Sulphur oxides, hydrogen sulphide	Moisture, ozone, sunlight, particles, mechanical erosion, microorganisms
Paper	Embrittlement, discolouration	Sulphur oxides	Moisture, physical wear, acid introduced in manufacture
Photographic materials	Small blemishes	Ditto	Moisture particles
Textiles	Soiling and reduced tensile strength	Sulphur and nitrogen oxides	Moisture, particles, light, physical wear, washing
Textile dyes	Fading, colour change	Nitrogen oxides	Ozone, light, temperature
Leather	Weakening, powdered surface	Sulphur oxides	Physical wear, residual acids introduced in manufacture
Rubber	Cracking		Ozone, sunlight, physical wear

contain calcium carbonate or calcium sulphate are particularly susceptible. The pigments in paint can make paintwork susceptible, and humidity encourages metal corrosion.

A second major factor is the *delivery of moisture*, gases and particles to the material surface. The physical location is important in this — the levels of pollutants may, for example, be higher at street level than on the tenth storey. A third major factor is the *physical force* of the delivery of pollutants, which is determined by air temperature, wind speed (which can, for instance, dry out wet surfaces more quickly and decrease the rate of corrosion), and the intensity, duration and amount of rainfall.

In precipitation with a pH less than 5.0, zinc and its surface coating of zinc carbonate become highly corrodible. A 1982 UN Economic Commission for Europe (UNECE) report notes that zinc will corrode six times faster in polluted air than in clean air. [25] Readings taken in central Stockholm revealed that the rate of corrosion of zinc increased by 150% between 1938 and 1958. Carbon steel, galvanised steel, copper, nickel, lead and cast-iron can all be corroded in varying degrees. Even aluminium (window frames, for example) can be attacked by acid. Stainless steel and plastics are the most resistant to attack. The corrosion rate of carbon steel can be 10 times higher in industrial areas than in rural areas. According to the Swedish Corrosion Institute, concrete may be corroded in soil or water with pH values below 6.0. This has led to concern for the durability of concrete bridges, dams and other structures. [26]

The city of Kraków in Poland, one of the first to be included on the UNESCO list of sites of the world's cultural heritage, is downwind from Poland's industrial heartland. Its medieval buildings are under severe threat from the now frequent — and acidic — smogs that have made Kraków one of the most polluted cities in Europe. The city's buildings are corroding, and their walls and roofs are being weakened. So much of the gold roof on Kraków's 16th century Sigismund Chapel of Wawel Cathedral was dissolved that it had to be replaced in 1980-81. [27]

There are more than 100,000 stained-glass windows in Europe, the oldest of which — such as the Window of the Prophets in Augsburg Cathedral (West Germany) — are about 1,000 years old. There is evidence that much of this glass survived in relatively good condition until the turn of the century. Much survived even the Second World War, when many stained-glass windows were taken down and stored. Within the last 30 years though, damage has occurred which gives reason to fear that unless effective measures of protection are taken, the staining in many windows could fade within 10 to 20 years.

Figure 4. Air pollution damage to materials. Source: J.E. Yocom and N.S. Baer — "Effects on Materials", in The Acidic Deposition Phenomenon and its Effects, *US EPA Critical Assessment Review papers (draft) Vol. 2 (Washington DC, 1983).*

Fred R. Conrad/New York Times

Acid corrosion. In 1984, the Statue of Liberty was partly dismantled for restoration. Nearly a century in the polluted air of New York City had severely corroded its iron frame and copper cladding.

Up to 2.5 cm (one inch) of the Portland stone on London's St Paul's Cathedral — which survived the wartime blitz — has been eaten away. Damage to Cologne Cathedral in West Germany costs £1.5 million annually. Buildings in Rome (including the Coliseum and Trajan's Column), Bologna, Venice and Florence are deteriorating, as is the Acropolis in Athens, and the Statue of Liberty in New York, which was partly dismantled in 1984 for major repairs.

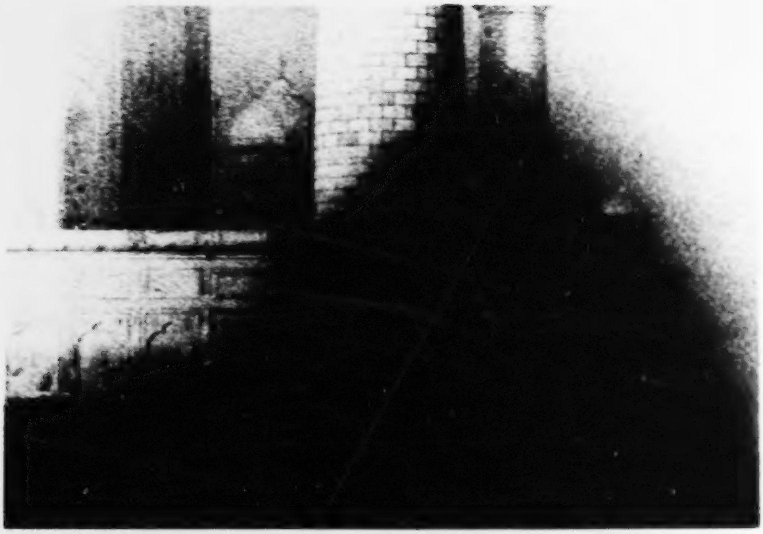
In India, there is concern for the future of the Taj Mahal. Emissions from an oil refinery built during the 1970s upwind from the Taj threaten the monument's marble and sandstone surfaces. Pollution spreading indoors is suspected of damaging paintings, and has so concerned several major US libraries and museums that they have fitted scrubbers to their ventilation systems. [28]

The corrosion of materials can lead in turn to other, often more dramatic, effects, such as metal failure. This could interfere with the airworthiness of an aeroplane, the structural strength of a bridge, or a vital electrical contact. A thin film of oxides could be formed on the electrical contact points in a computer, for example, so that in theory, a film no thicker than 0.0001 mm could break down the operations of an entire industrial plant. Much of this is conjecture, but sulphur corrosion was implicated in the collapse in 1967 of a steel highway bridge between West Virginia and Ohio in the United States, killing 46 people. [29] In the Katowice region of Poland, acid pollution is blamed for corroding railway lines to such an extent that in places, trains were only allowed to travel at 40 kph (25 mph) in 1981. [30]

Corrosion underground is even less visible. Submerged water pipes, sewage pipes, telecommunication networks, electricity supply networks, galvanised road culverts, galvanised pole butts, anchor stays and wires, sluice gates and piping in power stations can all be affected. Water pipes can be damaged from within and without. When copper pipes are attacked, the copper is dissolved in water and can cause discolouration of sanitary items and textiles, and even colour hair green. Polluted air can corrode paper, leather, textiles, plaster and household electrical contacts.

The UNECE review recorded that the cost to countries affected by atmospheric corrosion from sulphur compounds is estimated in national and international studies to be between $2 and $10 per capita per year, or between 0.10% and 0.23% of Gross National Product. With a population of 650 million, the costs to Europe could therefore be between $1.3 billion and $6.5 billion per year. In Sweden alone, the cost in corrosion to materials of all kinds has been estimated at $2.5 billion. [31]

A 1980 study for the Dutch Ministry of Health and Environmental Protection estimated that damage to monuments, libraries and archives in the Netherlands was costing $10-15 million a year. A 1981 OECD study of damage in 11 of its member countries in 1974 to galvanised steel and



Brian Johnson/Earthscan

The Taj Mahal, India. Smoke from an upwind oil refinery may be irreparably damaging the Taj Mahal. The more delicate carved projections could crumble away to gypsum in a matter of decades.

painted steel alone concluded that a 37% reduction in sulphur emissions would have saved nearly $1 billion at 1979 prices. The US Environmental Protection Agency estimated as long ago as 1974 that SO_2 emissions caused damage worth $2 billion to buildings in the United States. In Canada, it was estimated in 1979 by the US/Canada International Joint Commission that acid rain caused about half the man-made corrosion of cars.

Chapter 3

Reducing and controlling acid pollution

Speaking at the 1982 Stockholm Conference on Acidification of the Environment, James MacNeill, OECD's environment director, observed that emission control was no longer primarily a technological issue, because the technology existed and was known to work. "Neither is the issue the balance between the costs and benefits of control", he said. "The *principal* issue and the main source of controversy is *who* should bear the costs, *how* should the costs be borne, and *when*." The costs cannot be avoided; sooner or later someone will have to pay, whether it is industry, the taxpayer or the human environment.

There are obvious technical, economic and environmental advantages to equipping a power station or smelter with emission controls from the outset. Retrofitting is another matter. Many governments and energy authorities baulk at the costs involved in retrofitting thousands of existing industrial plants, and plead the case for more certainty about the economic benefits. The view of many scientists and acid pollution lobbyists is that *any* decrease in deposition will benefit the environment and people's health, so any control measures applied are better than none at all. Experts at the 1982 Stockholm Conference concluded that "the mere fact that better technology *may* come along in the future would not justify us in waiting and delaying the utilisation of already existing technology for the reduction of emissions".

There are four main routes to cutting pollutive acid emissions: using low-pollutant fuels, preventing the formation of pollutants during combustion, screening pollutants from exhaust and flue gases, and energy conservation.

Using low-sulphur coal and oil is the simplest way of reducing sulphur emissions from fossil fuels, but supplies of low-sulphur fuels (especially oil) are limited. Low-sulphur crudes are almost always light, and are more expensive because they yield more valuable refined products. They account for only a fifth of total world oil reserves and for about 30% of total oil production in 1980. The regions with the biggest reserves of oil — the Middle East (55% of world reserves) and Latin America (nearly 11%) — produce crude oil with a high sulphur content (1.4-1.6%). Hence future oil supplies will continue to depend heavily on high-sulphur oil.

Reserves of low-sulphur coal (containing 1% sulphur or less) are more plentiful (100% of Australian and western US reserves, for example, and 90% of South African reserves), but are unequally distributed. For example, a shift to low-sulphur coal is difficult in the United States because the biggest market for coal is in the east (which uses mainly high-sulphur midwestern coal), while the biggest low-sulphur reserves are in the west. Boilers in many plants were designed to use high-sulphur coal and would need expensive refitting to use low-sulphur coal efficiently. [32] The US coal industry is also worried that a switch to low-sulphur coal would threaten jobs in the high-sulphur mines of the east.

Control before combustion

The amount of sulphur and nitrogen given off by fossil fuels can be reduced by exposing the fuels to physical or chemical processes that remove some of the sulphur or nitrogen before combustion.

Coal is normally cleaned as a matter of course to remove incombustible particles of sand, clay and other materials. The cleaning usually takes place at the mine, and produces coal with a higher energy value, a less variable sulphur content and reduced ash content. It can cost less to ship, handle and store, has better boiler reliability and — because of the reduced slagging (formation of cinders) — reduces the costs of maintaining boilers. On the other hand, the cleaning process also produces high-sulphur waste which can contaminate groundwater, and about 10% of the energy content of coal is lost in the process. [33]

The sulphur in coal is partly pyritic (fixed to mineral grains in the form of iron sulphide) and partly organic (a chemically bonded part of the coal itself), usually in equal proportions. Coal washing is a relatively simple matter of crushing the coal and putting it through a large water tank. In the most efficient processes, up to 50-90% of the pyrite can be removed from hard coal. Removing organic sulphur demands more complex and expensive chemical processes, based for example on the use of microwave energy or electron beams (a method still in its infancy). Chemical treatment can remove both pyritic and organic sulphur, but most methods are still at the pilot study stage, and none are in commercial use.

One apparently cheap and simple coal cleaning technique still in its experimental stages uses a dry electrostatic process to remove pyritic sulphur and ash from crushed coal. [34] The coal is fed into a rotating drum and electrostatically charged. The coal particles are attracted to the drum, and the sulphur and ash are thrown free. Trials suggest that the system — developed by the US firm Advanced Energy Dynamics — can remove 30-68% of sulphur and 50-60% of the ash. Trials funded by the US Environmental Protection Agency achieved a 52% sulphur removal at less than half the cost (per tonne of product coal) of conventional washing methods.

Coal cleaning is used commercially in several countries, including West Germany and the United States, where the benefits — the improved quality of the cleaned coal and the cost-benefits of controlling sulphur emissions — easily justify the slightly increased fuel costs. In the United States, 40% of the hard coal and lignite coal produced in 1976 in 11 eastern and midwestern states was cleaned. The result was an estimated reduction in SO_2 emissions of 2.4 million tonnes. If all coal produced in these states was treated with currently available technology, SO_2 emissions could be reduced by more than five million tonnes [35] — a more than 20% reduction on total US emissions.

Coal cleaning has a significant potential for reducing SO_2 emissions throughout Europe. The OECD has estimated that if all the hard coals (coals other than lignite) used in Western Europe were washed, SO_2 emissions could be reduced by about a million tonnes a year (5% of annual total) at an annual cost of $350 million. If all the coal produced in the United Kingdom was cleaned like this, for instance, Britain could cut its estimated 1985 emissions by 13%. Its reliability and relative low cost make it an attractive possibility for controlling Third World sulphur emissions.

Oil desulphurisation. During refining, most of the sulphur in oil ends up in heavy oils with a sulphur content of 3-5.5% (compared to 0.2-0.7% in light oils). The sulphur content of these heavy oils can then be reduced to as little as 0.5% by techniques already widely used in refineries.

Indirect oil desulphurisation (or hydrodesulphurisation) is a simple and commercially well established technique, particularly in Japan. During refining, the light oils (or distillates) produced by the distillation of crude oil are distilled again, this time under vacuum. The product of this second distillate is 'hydro-treated', so that the sulphur is made to react with hydrogen. This hydro-treated distillate is then blended with the heavy oil to yield a low-sulphur fuel oil product. This can reduce the original sulphur content of the oil by 30-42%. [36] The different factors involved make it difficult to estimate the overall cost of oil desulphurisation, but estimated costs for oil with a sulphur content of 1-3% range from $17-40 per tonne (1980 prices), depending on the process chosen.

According to OECD calculations, indirect desulphurisation capacity in Western Europe could be increased from its present level to reduce SO_2 emissions by about three million tonnes (or 15%). But the declining demand for fuel oils, and the world oil surplus (including naturally low-sulphur oils) has generally discouraged oil companies from investing in desulphurising equipment. In addition, few European countries other than Sweden have stringent regulations on sulphur content in heavy fuel oil. Direct desulphurisation, which is potentially far more effective, has not yet been commercialised. In this method, the residue from the initial distillation is reacted with hydrogen and then reblended with the distillate to produce a lower sulphur oil. Alternatively, both the residue and the distillate are separately hydro-treated before reblending. This can result in up to 90% of the sulphur being removed. [37]

Control during combustion

The burning of fuels can be controlled to reduce the amounts of sulphur and nitrogen compounds released into the gas stream. Methods developed so far have been aimed at reducing both sulphur and nitrogen oxide emissions. Most have just been introduced, or are about to be introduced commercially. Because of the time needed to plan, design and build new furnaces, most of these systems will not provide anti-pollution dividends for some time to come.

Lime Injection in Multistage Burners (LIMB). This technique, still under development, controls SO_2 and NO_x emissions and is basically a combination of the low-NO_x burning method (see below) and sulphur removal methods. Where powdered coal is used, an absorbant (usually powdered limestone) is injected into the firebox and the combustion temperature lowered by using special burners. The limestone reacts with the sulphur to convert much of it into calcium sulphate dihydrate (gypsum).

LIMB can cut SO_2 emissions by up to 80% and NO_x emissions by half. It can be cost-effectively retrofitted into existing plants. The capital investment of $30-40 per kilowatt of plant capacity is far lower than for flue gas desulphurisation (FGD — see below), making LIMB even more attractive for retrofitting in plants and installations where FGD cannot be installed because of a lack of space. The costs of retrofitting have traditionally been used to argue against immediate action to reduce emissions from existing plants. The availability of LIMB undermines this argument to some extent.

Simple, low-cost techniques similar to LIMB have been developed in several countries (including Austria, East Germany and West Germany) to remove sulphur from brown coal. Calcium oxide, calcium carbonate or calcium hydroxide is added to the brown coal before combustion. These so-called dry additive processes can remove 40-60% of the sulphur.

Fluidised bed combustion. In this system, the fuel is burned in a perforated bed containing mineral material (generally limestone or dolomite) and residual ash from previously burned coal. Air is blown into the combustion chamber, causing the particles to float freely and behave as a liquid — hence the term 'fluidised bed'.

Combustion takes place without visible flames at a temperature of about 850-900°C (1,560-1,650°F), much less than the 1,650°C (3,000°F) needed in conventional coal-fired systems. The lower temperature reduces the formation of NO_x from nitrogen in the air, but has less effect on the oxidation of nitrogen in the fuel. Most of the SO_2 reacts with the bed material to produce gypsum. SO_2 removal rates of up to 90% are possible.

All the available information indicates that the fluidised bed technique is economically competitive with conventional coal-fired systems. One clear advantage is that both high-grade and low-grade coal can be used, making fluidised bed plants often more economic than stoker-fired plants. For small plants, fluidised bed combustion is often the only economically feasible desulphurisation method.

NO_x reduction during combustion. Because NO_x is formed by the effect of combustion on nitrogen in the air and in the fuel, lowering the combustion temperature and reducing the time air stays in the combustion chamber can reduce NO_x formation. The simplest option is to modify the burner so that the fuel and air mix slowly, reducing the intensity and temperature of combustion. The air used in combustion is split into several streams and introduced into the flame in stages. Low-NO_x burners like these can cut NO_x emissions by a half.

The attractions of low-NO_x burners are that NO_x reduction becomes part of the plant design and operation, and equipment costs are relatively low. A low-NO_x burner may cost 50% more than a regular burner, but this amounts to only about 2% of the total cost of the whole boiler. But if NO_x emissions are to be reduced significantly, low-NO_x burners and other similar staged combustion processes must also be retrofitted into existing plants.

Post-combustion control

Flue gases can be treated to make them cleaner, and controls can be applied to road vehicles to filter exhaust emissions.

Flue gas desulphurisation (FGD) has been used commercially for several years, and is the most immediate and widely used method for reducing SO_2 emissions. More than a thousand plants all over the world (most of them in Japan) already use it. The process removes much of the SO_2 formed during combustion by spraying or 'scrubbing' the flue gases (exhaust gases) in the chimney with a chemical absorbent, usually lime or limestone. There are two types of FGD: wet and dry.

The *wet scrubbing* process is the more widely used of the two, and was first introduced in Japan and the US in the mid-1960s. Two types of wet scrubbers are currently in operation: those using a recovery process, where the absorbent is regenerated and recirculated to the system, and those using non-recovery. Non- recovery — by far the more widely used — uses lime or limestone, sodium alkali, or dilute sulphuric acid as an absorbent, and can remove 90-95% of the SO_2 formed during combustion.

The costs of wet FGD vary with the different processes and with local needs and conditions, but investment costs generally come to 15-20% of the total cost of a power plant. Energy costs might increase by about 10%. The removal of one tonne of sulphur can cost $400-1,000.

The biggest disadvantage with wet FGD systems is that they produce a sludge. Limestone scrubbing produces a calcium sulphite and calcium sulphate mixture with the consistency of toothpaste, which is difficult to dehydrate, store and handle. In a typical 1,000 MW plant, burning coal with 3.5% sulphur, wet FGD produces about 225,000 tonnes of sludge annually. A recent report [38] concluded that the US will produce more sludge from FGD scrubbers than from the treatment of municipal sewage. Wet FGD also raises the problem of how to prevent toxic metals like mercury leaking from residual fly ash and sludge and contaminating groundwater. But sludge can be chemically treated to reduce the water content and improve its compressive strength.

Recovery processes are more expensive and energy-intensive, so have not yet been widely used except where other factors — such as limited space for sludge disposal — have had to be taken into account. One major advantage of recovery is that sulphuric acid or pure sulphur can be extracted from the sludge waste and sold commercially. The calcium sulphite can also — using air oxidation — be converted into gypsum. Japan has little natural gypsum, so has developed ways of purifying and marketing this gypsum.

Dry scrubbing can use two different processes. Either lime slurry is sprayed into the flue gases and absorbs the SO_2 (the slurry is dried at the same time), or (in the Walter FGD method) ammonia is sprayed into the gases, producing pelletised ammonium sulphate as a dry end product. The pellets can then be used as fertilisers.

Dry scrubbers produce waste that is easier to handle and use, have fewer operating problems, and have lower capital, operating and maintenance costs. They also use much less water than other systems. But although dry scrubbers can remove 70-90% of the SO_2 from combustion, they are not yet widely used, mainly because they are most effective with low or medium sulphur coals. Commercial plants are already in operation in Sweden, and they clearly have potential elsewhere in Europe.

The electron beam method. One flue gas desulphurisation process still at the pilot stage promises simultaneous removal of SO_2 and NO_x, plus the production of a saleable by-product, by actually creating 'acid rain' at source. Flue gas is sprayed with water to reduce its temperature to 60-90°C (140-195°F), and then with ammonia. The cooled gas mixture then passes through an electron beam reactor which turns the oxides into acids. These react with the ammonia and water vapour to form ammonium compounds that could be used in fertilisers. Laboratory tests have shown that 80-92% of the SO_2 and 50-90% of the NO_x can be captured. Trials by the US Department of Energy's Advanced Environmental Control Technology Program began at two US power stations early in 1984. [39] Another E-beam system being tested at a Tennessee Valley Authority power plant produces calcium sulphate, nitrate and ash which can be reacted with lime to produce a solid substance suitable for landfilling.

Flue gas treatment for NO_x reduction. Several attempts have been made to develop post-combustion techniques that remove NO_x from flue gases, and there are now at least 50 such processes. [40] Some methods are currently being used in Japan in oil-fired boilers.

Most commercially applied flue gas denitrification methods use selective catalytic reduction (SCR), where ammonia is added to the furnace exhaust gases and the mixture subsequently passed over a fixed bed catalyst. This can remove 80-90% of the NO_x and convert it into elementary nitrogen. The problem is that SCR is more expensive than the low-NO_x burner, so it is doubtful how widely it will be used. NO_x reductions of 40-70% have been achieved with non-catalytic reduction, where ammonia is injected directly into the combustion zone. The OECD estimates capital costs of SCR at $15-60 per kilowatt of plant capacity (depending on boiler size and whether heat recovery systems are included), and $7-15/kW for non-catalytic systems. The OECD also estimates that NO_x reductions of 20-40% in the Netherlands and Japan are expected to increase either prices or unemployment by just under 1%. [41]

Cutting vehicle emissions

Catalytic converters. As the source of 33-50% of man-made emissions of NO_x (the proportion varies by country), road traffic is a major target for emission control technology. The most widely available system (for petrol-driven vehicles, but not for diesel) is the catalytic converter, already widely used in the United States and Japan).

The three-way converter reduces emissions of NO_x, carbon monoxide and hydrocarbons. Fitted to the vehicle exhaust (tailpipe), it contains either beads or a honeycomb-like structure coated with a precious metal combination of platinum (85%) and rhodium (15%). About two grammes of precious metal is needed for each converter. The spent exhaust gases from the engine pass through the converter, which oxidises CO (carbon monoxide) and HC (hydrocarbons) to CO_2 (carbon dioxide) and H_2O (water), and reduces NO_x to nitrogen. CO, NO_x and HC emissions can be reduced by up to 90% in a motor vehicle in ordinary traffic, provided the converter is well maintained.

But the three-way converter also has three disadvantages. First, it is complex. In order to function effectively, the air/fuel mix in the

Martin Mayer/Network

Road traffic, London. Motor vehicles produce between one-third and one-half of man-made nitrogen oxides. Fitting exhaust filters could reduce NOx emissions, but there are doubts about their cost-effectiveness. British car makers are more interested in 'lean-burn' engines.

combustion chamber must be carefully controlled. Second, it is sensitive to lead and so is no use in the many countries that still rely wholly or largely on leaded petrol. Third, it is fairly expensive. The annual average cost (purchase of the converter plus maintenance over 10 years) has been put at anything from $60-80 upwards per car.

The catalytic converter appears effective, but doubts have recently arisen about its long-term benefits. US studies show that illegal switches back to leaded petrol (which is cheaper than unleaded petrol in the United States) and improper operation and maintenance can substantially reduce the effectiveness of converters. Hence their use needs to be compulsory, or linked to public education about the long-term environmental and health benefits of using converters.

Attempts to change the design of car engines, such as the 'lean-burn' research programme run by Ford, may produce methods as effective as the catalytic converter for the reduction of exhaust gas emissions. British motor manufacturers — among others — argue that lean-burn engines offer more durable and cheaper emission controls, and that catalytic converters have actually interfered with attempts to increase the fuel efficiency of new cars. European motor manufacturers have argued that European driving conditions — including stop-start motoring and higher motorway speeds — mean that converters will not perform as well as they have in the United States, which has less congested roads and a blanket speed limit of 90 kph (55 mph). This has been disputed by Johnson Matthey, the world's biggest manufacturers of converters, which quotes a recent test in which a vehicle fitted with a converter was driven for 80,000 kilometres (50,000 miles) at an average 170 kph (105 mph) and still met US emission standards at the end of the test. [42]

The costs of pollution control

Cost is the most common element in arguments used by governments and industries opposed to taking action to control emissions. They fear that emission controls will add to the costs of using coal and oil, that the economic advantages of coal over other fossil fuels will be reduced, that the costs will have to be passed on in higher fuel bills to the consumer, and that production levels will decrease and unemployment levels increase.

The position is very confused. A 1982 OECD symposium on the costs of coal pollution abatement pointed out that the data then available on SO_2 abatement costs had "an unacceptable range of variation". [43] Costs for wet FGD varied from $72 to $207/kW, a range which reflected differences in plant capacity, sulphur removal rates, the sulphur content of coal, and varying methods of accounting.

The confusion is reflected in the varied (and often exaggerated) estimates made by the electricity industries in the United States and Britain. The US electrical industry estimates that a 30% SO_2 reduction from 24 generating stations would eat up 23-58% of total cash flow, double the capital costs, treble the operating costs, and raise electricity prices by 5.7% over a decade. Britain's Central Electricity Generating Board (CEGB) warned in 1983 that Britain faced a bill of £4 billion ($5.2 billion) and annual costs of £700 million if SO_2 emissions were to be reduced threefold. By 1984 it was talking of a total bill of £2 billion for a 30% reduction, an estimate dismissed by *The Guardian* newspaper as scare tactics. The CEGB has estimated a rise in electricity prices of anything from 4% to 10%, and has warned of the dangers of increased unemployment.

These figures contrast dramatically with the conclusions of the 1982 OECD symposium, which heard evidence that the average costs for controlling emissions came to about 4% of total plant capital costs, and that operating costs would increase by about 2%. The simplest modifications, resulting in NO_x removal of 10-30%, would add no more than 1% to capital costs and 0.5% to running costs. Research and development in the United States and Japan promises to reduce the costs of pollution control by 10-20% by the end of the decade, and by as much as a third in the long term. The LIMB process in particular could reduce the control costs for low sulphur coal by as much as 60% if it were commercialised successfully.

Energy conservation

Most of the debate over controlling acid pollution has centred on methods of reducing the amount of emissions caused by fossil fuel combustion. Relatively little attention is paid to actually reducing the amount of fuel burned in the first place: energy conservation. The developed countries that account for 80% of the world's consumption of commercial energy still rely largely on methods developed in an age of cheap and plentiful energy, when efficient use of energy was less important. Hence many of the technologies used in power stations are grossly inefficient, a great deal of energy is lost during conversion and distribution, and end consumers in the public and private sectors use energy inefficiently.

Britain provides an example of the inefficient use of energy. According to the influential *A Low Energy Strategy for the United Kingdom*, published in 1979, Britain could actually cut its energy consumption by half at no cost to its standard of living or level of economic activity. [44] Most British power stations — which generate more than 80% of Britain's electricity — have poor thermal efficiency, so that as much as two-thirds of the heat generated by a power station can be lost because of the low efficiency of converting coal to electricity. Up to one-fifth of the UK's primary energy is lost through the cooling towers of power stations. More losses are sustained through inadequate insulation at the point of consumption — in factories, businesses, shops and private homes.

Transport provides similar problems. The number of road vehicles has been increasing steadily throughout the world. In Britain there has been a 400% increase since 1953, and three times as many kilometres are now travelled in cars than in all other forms of land transport combined. Road vehicles are still far from being fuel-efficient, partly because of body and engine design and partly because of the way they are driven. As little as 12% of the fuel put into a car is actually converted into useful motive power at the wheels. Nearly 62% is expelled by the exhaust or used up in cylinder cooling, and much of the rest is lost in air drag and tyre drag. The most efficient use of petrol is made in cars travelling at a steady 90 kph (55 mph). The blanket speed limit of 90 kph imposed in the United States helped reduce national petrol consumption there by one-fifth between 1978 and 1984.

World energy consumption is predicted to grow by 225% in the next 40 years. William Chandler of the Washington-based Worldwatch Institute observes that if this prediction comes true, sulphur emissions will — without emission controls — increase by 265% over current levels. "Energy conservation could hold these releases to a 35% increase," he notes, "and make the use of emission controls more affordable and feasible." [45]

Energy conservation, improved energy-use efficiency, speed limits, and the increased use of public transport could all help industrialised countries in particular to reduce the quantities of fossil fuels burned, and thereby lead to a reduction in the quantity of pollutive emissions. Because of its low costs and quantifiable economic advantages, conservation has a particular immediacy in developing countries striving to reduce their oil and coal import bills.

Liming: treating the symptoms

Liming counters acidity by helping restore the natural buffering capacity of lakes and watercourses. Lime, limestone and dolomite have been used for the liming of lakes, streams and rivers in Sweden, Norway and Canada since the mid-1970s. Sweden has the most complete experience and documentation of liming. A test programme was started there in 1976, and large-scale liming has been in progress since 1982. Two methods have been used: spreading lime (mostly in the form of finely crushed limestone) directly into the water, or liming the land around the lake and the small brooks feeding the lake with water.

When lime is added directly to the lake, much of it is absorbed and pH values immediately fall. Between 50-90% of the lime is 'taken up' in the direct spreading. Liming surrounding land or catchment areas has less immediate effects (the lime flows into the lake water at an estimated rate of about 2% per year) but has ecological advantages. It neutralises the acid deposition before it reaches the lake, and prevents the leaching of aluminium and other toxic metals from the soil at the same time as it restores the bicarbonate content of the soil water. But the relative costs of catchment area liming are much higher because of the small proportion of lime that reaches lakes during the course of a year. It can also harm wildlife.

About 3,000 Swedish lakes have been limed to date, with the following results:

- The water has been rapidly recolonised by plankton and winged insects;
- reproduction of fish has been restored in lakes where there were still

HansOstbom

Liming lakes, Sweden. Liming is one way of treating the symptoms of acidification in lakes. About 3,000 Swedish lakes have been limed so far, but it is only a stop-gap measure.

enough fish left. (In severely acidified lakes with no fish, new stocks must be introduced at additional costs);

- sources of nutrition for amphibians and fish-eating birds have been restored;
- mercury content in fish has decreased, since the metal is once again fixed to the bottom sediments.

But liming has had many drawbacks. Metals from surrounding land have continued to wash into lakes, carried by acid soil water. Metals released from the lake sediments during acidification have remained. Although temporarily fixed by the added lime, they are not rendered permanently harmless. If liming stops or goes below a critical level, the metals go into solution again. So liming is habit-forming.

The turn-over time of the water determines how often the liming should be repeated. In Sweden, liming generally lasts about three to five years, but Norway's test programme has had short turn-over times. Norwegian acidified lakes are mostly small and situated in the upper reaches of water systems with small catchment areas. The direct input of acid water and the short retention time of the lake water makes it difficult to maintain the positive effects of liming for any length of time.

Acid surges (especially during snow-melt) are difficult to control with liming. If acid surges have already killed fish fry and other organisms in the sensitive spawning season, raising the pH of the lakes is futile.

Many watercourses are difficult to lime; maintaining adequate pH levels in longer streams is particularly difficult. In mountain streams the water may run so fast that not even a soil naturally high in lime has time to neutralise the runoff. Attempts to lime running waters, streams and rivers have been discouraging. The equipment used to add the lime to the waters continuously is expensive and is neither very efficient nor very reliable. Lake liming costs about $30 per tonne of lime spread. By 1984, the Swedish liming programme had cost $25 million.

Above all, though, the major doubt about liming is that it is an artificial chemical attempt to maintain 'natural conditions' in freshwater ecosystems, and that it is tackling the symptoms rather than the causes.

Liming soils and groundwater. A Swedish test programme was launched in 1982 (using dolomite in combination with ash and added phosphorous, potassium and boron as a liming agent) to study ways of countering soil and groundwater acidification. So far $2 million has been spent on the programme. Forest land liming has not been carried out long enough to show any hard results, but evaluations of forest land limed 15-20 years ago (with the aim of improving site quality in general) offer little cause for hope or optimism. The liming has damaged soil organisms and leached nitrate from the soils, and rather than encouraging forest growth, has actually impaired growth.

In the longer term, soil liming can raise the pH value and cation content of the soil, make aluminium less mobile, and help keep soils healthier until the acid deposition is reduced to the point where natural neutralising systems can take over. Liming could, at best, maintain adequate soil conditions and prevent an increase in stress to trees subject to continued direct pollution damage. Once emissions decreased and direct damage stopped, the better soil conditions would promote tree growth.

Chapter 4

Acid pollution as an international issue

Fifteen years ago, acid pollution was a phenomenon almost unknown to anyone but a handful of scientists. Today it is a major political, economic and environmental issue, straining relations between governments, dividing countries into polluters and polluted, and testing the political will to protect the environment.

Action to date has been characterised by seven main principles:

- Much of the action has been curative rather than preventive.
- The level of government interest and action is usually in direct proportion to the degree of damage identified at home. The Scandinavians and Canadians have been the most vocal; the West Germans changed course only when faced with proof of substantial damage within their own borders, and Britain — where relatively little damage is officially acknowledged and where acid pollution is barely a public issue yet — has so far steadfastly refused to act.
- Governments are often concerned less with whether to act to curb emissions than with who should pay the costs involved.
- There has traditionally been a marked lack of governmental interest in taking action on matters that do not have immediate national benefits. The only costs seriously considered by governments are those involved in reducing emissions. Theoretical estimates of the cost of damage to crops, forests, lakes, fisheries, health and buildings carry little weight in political decisions.
- Those governments least willing to act repeatedly quote "scientific disagreement" as an excuse, or make appeals to self-righteousness. "Why blame us? We only contribute a fraction of the emissions."
- There has been difficulty in taking international cooperation beyond scientific cooperation and information exchange — to take concrete preventive measures.
- As a problem with long-term effects and solutions, acid pollution is often seen as beyond the short-term political agenda.

The background

Although acid pollution has only recently become an issue, air pollution caused by the burning of fossil fuels has been known of for centuries.

Pollution from coal burning was a problem in 14th century England, when an unsuccessful attempt was made to ban Londoners from burning sea-coal because of the smoke it produced. The 17th century naturalist and diarist John Evelyn wrote of the "hellish and dismal cloud of sea-coal which maketh the City of London resemble the suburbs of hell", and in 1727 London's air was described as "full of acid and sulphureous particles".

In the 1850s and 1860s, the British chemist Robert Angus Smith noted the correlation between coal burning and acid pollution in and around the industrial centre of Manchester, where he identified three kinds of air: "that with carbonate of ammonia in the fields at a distance,... that with sulphate of ammonia in the suburbs,... and that with sulphuric acid, or acid sulphate, in the town". His book *Air and Rain: the Beginnings of a Chemical Climatology*, published in 1872, was the first outline of the process of acidification, noting the connection between the burning of coal, wind direction, corrosion and acid damage to vegetation. Many of his findings and conclusions still hold true today.

Acidification of lakes was probably behind the decrease in fish populations in southern Norway at the turn of the century, and the extinction of trout in several lakes, although the reasons were not then known. In Canada, the late 19th century open bed roasting of high-sulphur copper ores destroyed vegetation in the vicinity of Sudbury, Ontario and ruined crops in neighbouring farms. By 1916 the farmers were agreed that action was needed, but instead of dealing with the source of the pollution, the government merely declared local areas "unfit for cultivation". In 1924 a farmer from Manchester, England, sued the power station at Barton for compensation, arguing that its sulphur emissions were damaging his crops. His claim was rejected by the House of Lords, but the case generated considerable public debate.

During and after the Second World War, the Swedish scientist Hans Egner began a systematic study of how vegetation could receive nutrients through the deposition of airborne substances. This system was developed further by the International Meteorological Institute (IMI) in Stockholm (Sweden), which began a systematic record of data on precipitation in 1956 (a similar programme was run in the United States in 1953-55).

Also in the 1950s, the Canadian ecologist Eville Gorham published a series of papers in which he argued that acid precipitation could affect the buffering capacity of bedrock, soils and lakes. Working in England, Gorham and a colleague found acidified lakes in Cheshire and acidified pools in the Lake District, and noted that acid rain fell in the Lake District whenever the winds blew from urban industrial areas.

An estimated 4,000 people died from heart and lung ailments associated with the effects of the London smog of 1952, and many more fell ill. Californian environmental engineer Michael Hoffmann has estimated that

Environment Magazine, USA

Coal-fired power station, Tennessee, USA. In an attempt to disperse pollutants on the winds, power station designers have made smokestacks higher and higher. Although this has often reduced local pollution, it has affected areas further and further away.

the smog had a pH of between 1.4 and 1.9, making it almost as acidic as battery acid. [46] Following the smog, smoke control regulations were rapidly tightened, and the Clean Air Act passed in 1956. In an attempt to control local air pollution in Britain and other industrial countries in the 1950s, tall smokestacks were built at many power stations and factories. Although these successfully curbed local pollution, they had the effect of dispersing much of the pollution to the winds, thereby affecting areas further away from the source of emissions.

Swedish researchers — notably the atmospheric chemists Erik Ericksson and Karl Gustav Rossby — became convinced that airborne pollutants were carried and deposited at various distances from their source. In the 1960s the Swedish scientist Svante Oden — a colleague of Ericksson and Rossby — established a link between industrial emissions and environmental damage (largely to fish and lakes). In 1968 he published a paper in which he argued that precipitation over Scandinavia was becoming increasingly acidic, and that large quantities of the sulphur compounds that caused the acidification came from British and central European industrial emissions. Europe was alerted to the fact that air pollutants could travel 1,000 km (600 miles) or more.

Swedish concern over the effects of acid pollution moved Sverker Astrom, the Swedish ambassador to the United Nations, to suggest the convening of an international conference to discuss environmental problems. The result was the UN Conference on the Human Environment, held in Stockholm in 1972. The conference heard a paper prepared by Oden and his colleagues, which described the possible transport of air pollutants over long distances and the consequent environmental damage. The team had combined a sequence of already known air pollution data, meteorological conditions over Europe and measurements of water quality changes in Swedish lakes, and emphasised particularly that the emission of air pollutants was a truly international problem. But there was still considerable scepticism outside Scandinavia about the links between pollution and acidification. The study attracted some interest, but had little result. Oden's team was accused of exaggerating the problems, and it was argued that even if there was some truth in the theories, the problem was limited to a handful of lakes and fish stocks in the far north.

The study did however contribute to the acceptance of Principle 21 of the Declaration of the Stockholm Conference, which pointed out that states have an obligation to ensure that activities carried out in one country do not cause environmental damage in other countries, or to the global commons. Another result was the establishment of the National Atmospheric Deposition Program in the US, which now maintains a network of sampling stations throughout the country.

Despite all the scepticism — or perhaps because of it — the OECD launched a four-year study called LRTAP (the Co-operative Technical

Programme to Measure the Long-Range Transport of Air Pollution 1973-77) in the 11 European member countries of the OECD. The aim was to reach a common understanding about the causes and effects of sulphur emissions, of possible transport within Europe, and of possible deposition and adverse effects hundreds or even thousands of kilometres from the source.

Nearly 80 observation stations were set up to take samples of the sulphur content of air and precipitation. The results, published in 1977, provided convincing evidence of the causes of acid pollution, and backed up the assumptions made by the Scandinavian scientists. It was concluded that airborne pollutants *could* and *were* being transported. It was made clear which countries were net exporters and net importers of pollutants. In five of the 11 participating countries (Finland, Norway, Sweden, Austria and Switzerland), more than half the total deposition of sulphur was estimated to come from foreign sources. [47]

James MacNeill, later OECD environment director, observed that the survey had shown that "precipitation in one country was, without doubt, being measurably affected by emissions from sources in other countries". The LRTAP project also revealed that the problems were not confined to Western Europe. On the contrary, they involved all European countries north of the Alps.

An observation programme was launched in Canada in 1975, and in 1977 the US Council on Environmental Quality (CEQ) launched an assessment programme that provided the basis for President Carter's 1978 Initiative on Acid Precipitation. In 1980 the US and Canada signed a Memorandum of Intent on Transboundary Air Pollution (MOI), committing themselves to joint research. There has however been little further agreement; the United States has so far refused to join Canada in meaningful commitments to reduce SO_2 emissions in eastern North America.

Trends in the sulphur content of air have been difficult to gauge because of the lack of reliable long-term data. The IMI project now has data for nearly 30 years, however, which reveals that the sulphate content of precipitation in southern Scandinavia jumped at the turn of the 1960s from 55 microequivalents per litre to 90, since when it has remained more or less constant. The concentration of nitrates also rose from 15 microequivalents per litre in 1955-59 to 25 a decade later, and to 40 by the late 1970s.

The Convention on Long-Range Transboundary Air Pollution

Despite the OECD report, which provided the first independent verification of Scandinavian charges that imported sulphur was behind its acidification problems, the Scandinavians still found themselves virtually alone in promoting the air pollution issue in the international arena.

The change came with the 1975 Helsinki Conference on Security and Cooperation, when Soviet leader Leonid Brezhnev suggested that attempts should be made to reach agreement on three problems that were pan-European: energy, transport and environment. Only the latter was politically acceptable to the West, and with one condition: that the discussion should generate concrete results, rather than only rhetoric and general political statements. With this in mind the Nordic countries proposed air pollution as the major theme. The substance of the exercise was to elaborate a convention on long-range transboundary air pollution to be signed at the conference by all European states, the US and Canada. The UN Economic Commission for Europe (ECE), which includes both east and west European states, was designated as the competent body.

Sweden and Norway pressed for a tough convention that would call for a halt to increases in SO_2 emissions (the 'standstill' clause), together with a 'rollback' clause that specified SO_2 abatement by fixed percentage levels of up to 50%. Exceptions were to be made for countries that had either already implemented abatement measures (e.g. the Netherlands) or those in a relatively early stage of industrial development (e.g. Ireland). But a number of countries objected to legally binding controls. The opposition was led by the UK and West Germany, which were not even prepared at that stage to accept a commitment *not to increase* emissions.

After further negotiations, and pressure from France, Norway and Sweden, West Germany finally accepted a much watered-down convention. The final convention consisted of little more than a general obligation on each contracting party to "endeavour to limit and, as far as possible, gradually reduce and prevent air pollution including long-range transboundary air pollution". This was to be done with the use of the "best available technology which is economically feasible" in new and retrofitted plants. These terms, 'best available technology' and 'economically feasible', have subsequently been given wide and loose interpretation.

Swedish officials privately suggest that West Germany accepted the final convention text not out of environmental concern, but because Willy Brandt and Helmut Schmidt did not want to jeopardise the proposed high-level meeting as a part of their overall East-West policy for détente. Britain accepted the convention because it believed that its plans for increased reliance on nuclear power would bring a net reduction in emissions, so it could meet the terms of the convention without changing its existing energy or pollution control policies. [48] The Nordic plans for goals, timetables, abatement requirements and enforcement provisions were dropped.

The convention was signed in Geneva in November 1979 by 35 countries, including Britain, the United States, West and East Germany and France, and by the European Community. At the same time, a resolution was adopted requesting the signatories to start implementing the provisions of the convention on a voluntary basis, starting with sulphur emissions, until such time as the convention could enter into force. By March 1983, the 24 ratifications needed to bring the convention into force had been collected. By March 1985, 30 countries and the European Community had ratified.*

The convention was initially criticised for its lack of power, and even dismissed by critics as an excuse for doing nothing about large emissions. Yet it had symbolic value in that countries from Eastern and Western Europe, the Soviet Union and United States, all signed the document. Given the subsequent cooling of East-West relations, it is likely that no convention at all would have been possible a year or so after the Geneva meeting. The convention also deals not only with SO_2 but with other sulphur, nitrogen and chlorine compounds, polycyclic aromatic hydrocarbons, heavy metals, particles, and other substances. So it could in the long run prove useful in efforts to deal with pollutants other than SO_2 (including NO_x). It also strengthened the key European data gathering network — the Co-operative Programme for Monitoring and Evaluation of Long-Range Transmission of Air Pollutants in Europe (EMEP). EMEP, designed to provide information on the transboundary flow of air pollutants, has been operating since 1978 with 60 stations in 20 countries in East and West. Set up originally under the auspices of the ECE it is now run by the Executive Body of the Convention.

Stockholm 1982: a change of heart

The lukewarm response to the convention and the lack of public awareness and political will encouraged Sweden to use the tenth anniversary of the 1972 Stockholm Conference to draw attention again to air pollution. Sweden wanted a renewed political commitment similar to that expressed by governments at the signing of the ECE Convention. All the signatories to the convention were invited to the Conference on the Acidification of the Environment, held in Stockholm in June 1982. The conference was held in two stages: a scientific and technical meeting, and a ministerial meeting.

The first meeting, attended by experts representing themselves rather than their countries or governments, scrutinised all the scientific evidence of the causes, transport and effects of transboundary air pollutants, and the technical material available on strategies and methods (including costs) for the control of emissions. They arrived at four main conclusions:

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*Austria, Belgium, Byelorussia, Canada, Czechoslovakia, Denmark, East Germany, West Germany, Finland, France, Greece, Hungary, Iceland, Ireland, Italy, Liechtenstein, Luxembourg, the Netherlands, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey, Ukranian SSR, USSR, United Kingdom, United States, European Community.

- Man-made sulphur and nitrogen compounds were primarily responsible for acid deposition, and a decrease in emissions over a large industrialised region would lead to an 'approximately proportionate' decrease in acid deposition.
- A 'threshold value' of 0.5 grammes of sulphur per square metre per year for sulphur deposition was agreed; above that level, sensitive aquatic ecosystems would begin to be harmed.
- Technology was commercially available that could radically reduce emissions of air pollutants.
- The fact that improved technologies may emerge in the future did not justify waiting and delaying the use of existing technology.

The ministerial meeting adopted these conclusions, and concluded:

- that acidification problems were serious and that even if total deposition was not permitted to rise, damage to soil and water would continue to increase unless prompt action was taken within the framework of the convention. Such action was urgently needed and should include (a) the elaboration of concerted programmes for the reduction first of SO_2 emissions, and then of NO_x, and (b) the use of the best economically available control methods, including flue gas desulphurisation, low-sulphur fuels, desulphurisation of fuels, and new combustion technology.
- that the 'tall-chimney principle' was outdated and should be abandoned. Whatever pollution load tall chimneys may have removed from the local environment, the associated long-range, transboundary pollution was unacceptable.

These were positive conclusions. International agreement had been reached, and demands had been made for concrete measures. The absence of the USSR, Poland and Czechoslovakia was offset by West Germany's dramatic policy about-face announced at the conference. The growing momentum of the Greens was beginning to change the West German political agenda, encouraging Helmut Schmidt's Social Democratic government to adopt 'green' policies, and the first alarming reports of forest damage had begun to appear. It had become obvious that a position against acid pollution controls was no longer tenable. The West Germans now declared their intention to halve their SO_2 emissions in 10 years and to raise the question of the international environment at the next world economic summit; they pointed out that global success could only be achieved by concerted international action.

The 30% Club

Conferences seldom bring about radical changes, but the 1982 Stockholm Conference had one major effect: the process of ratifying the long-range transboundary pollution convention was speeded up. Within months, all the European Community countries had ratified, providing additional political momentum. One of the most substantive results was the Nordic proposal for a mutual 30% reduction of SO_2 emissions in the 10 years 1983-93, calculated from emission levels in 1980. This proposal was put to the signatories at the first meeting of the Executive Body (EB) of the Convention in Geneva in June 1983. Immediate support came from Canada, Austria, Switzerland and West Germany. The Nordic proposal was accompanied by one from Austria, Switzerland and West Germany calling for NO_x reductions too, but this was strongly opposed by the East European bloc, and ended up as a first step towards integrating NO_x in EMEP.

The Nordic 30% proposal was rejected by the EB; western countries (notably the UK, France and the US) were united with the Eastern European countries in their opposition. What came out of the discussions was "a recognition of the need to decrease effectively the total annual emissions of sulphur compounds, or their transboundary fluxes, by 1993/95 using 1980 emission levels as the basis for calculation". The term 'transboundary flux' (the volume of sulphur oxides that crosses national borders) was coined by the Soviet Union and its Eastern European allies to support their view that only pollutants actually exported should be dealt with in international cooperation. What happened inside a country, they argued, was strictly an internal matter. The East European countries agreed to cooperate in setting up air quality and precipitation monitoring stations and pooling the data thus gathered, but refused to make emissions data available, arguing that they would reveal sensitive economic and energy information. Limiting its commitment to 'transboundary fluxes' works in favour of the USSR, because prevailing westerly winds mean that most Soviet emissions do not affect neighbouring countries.

In March 1984, representatives from 10 of the countries that supported the Nordic concept of a 30% reduction in SO_2 emissions met in Ottawa to sign their own agreement to reduce the emissions that lead to acid pollution. The minimum requirement was an undertaking to reduce SO_2 emissions by 30% by 1993 (using 1980 figures as the baseline) — hence the agreement was dubbed the '30% Club'. France, West Germany, Canada and Norway went further by committing themselves to 50% reductions (that of France to be achieved by 1990), and Denmark and the Netherlands agreed to aim for a 40% reduction. The remaining original members were Austria, Finland, Sweden and Switzerland. The Ottawa conference also, for the first time, put NO_x high on the international

	Date of accession	*Agreement — all 30% by 1993 except:*
Austria	March 1984	50% by 1993
Canada	March 1984	50% by 1994
Denmark	March 1984	40% by 1995
Finland	March 1984	
West Germany	March 1984	50% by 1993
Norway	March 1984	50% by 1994
Sweden	March 1984	
Switzerland	March 1984	
France	March 1984	50% by 1990
Netherlands	March 1984	40% by 1995
Belgium	June 1984	
Bulgaria	June 1984	
Byelorussia	June 1984	
East Germany	June 1984	
Liechtenstein	June 1984	
Luxembourg	June 1984	
Ukraina	June 1984	
USSR	June 1984	
Czechoslovakia	Sept 1984	
Italy	Sept 1984	
Hungary	April 1985	

Figure 5. The 30% Club (as of April 1985).

agenda by declaring that the participating countries would "take measures to decrease effectively the total annual emissions of nitrogen oxides from stationary and mobile sources as soon as possible and at the latest by 1993".

By April 1985, 21 countries had joined the 30% Club. In addition to reducing SO_2 emissions, they have agreed to unspecified cuts in other pollutants, mainly NO_x.

A second major international conference was held in Munich in June 1984, with the partial aim of encouraging more countries to join the 30% Club. The conference (the Multilateral Conference on the Environment, 24-27 June 1984), attended by environment ministers from the countries within the convention, requested that the EB, at its second meeting in September 1984, should as a matter of priority adopt a proposal for a specific agreement on the reduction of annual national sulphur emissions (or their transboundary fluxes) by 1993 at the latest. It was also decided that total annual emissions (or transboundary fluxes) of NO_x from all sources should be effectively reduced by 1995, considering that several countries had already committed themselves to such reductions at an earlier date. The EB was also recommended to include NO_x in its work programme.

Given the strong opposition at the first EB meeting against even mentioning NO_x problems, these decisions were a breakthrough. But the United States still remained outside. The Canadian environment minister had said in Ottawa that if the Americans did not go to Munich, the Soviet Union would "take advantage of that opportunity to be forthcoming on pollution controls, just to appear to be on the side of the angels... US failure to provide international leadership on acid rain will create a vacuum which the Soviets may try to exploit." The US went to Munich, but said it could not agree to specific SO_2 reductions.

In December 1983 the Commission of the European Community proposed a Council Directive on large emission reductions in the member countries; 60% reductions of SO_2, 40% of NO_x and 40% of dust. Traditional thermal power stations were the main target, and the reductions were set for 1995. These stations account for more than 80% of SO_2 emissions and 40% of NO_x emissions within the European Community. This proposal was much inspired by the new West German legislation on air pollution. The Commission calculated that additional costs for reductions would amount to less than 10% of production costs. The annual costs of damage from acid pollution are at least comparable, if not higher. The OECD estimates the annual costs to the European Community of acid deposition damage to be between $50 and $65 billion (35% of the European Community Gross National Product).

The Commission has also suggested that all member countries should switch to unleaded petrol from 1989, but that it should be up to each country to introduce unleaded petrol whenever they wish, beginning in 1986. The Commission proposed that catalytic converters (US standards) should be fully introduced to all member countries by 1995 at the latest. Individual countries would again be free to introduce regulations earlier if they wanted to (see Chapter Eight).

Further evidence of a new level of interest in the international implications of acid pollution came in December 1984, when environment ministers from six of the seven Western Economic Summit countries met in London to discuss priority environmental issues. The meeting followed an agreement at the June 1984 economic summit that efforts should be made to identify environmental issues on which there was a need for increased international cooperation. There was no formal agenda, but acid deposition was at the top of the list in the letter of invitation sent to environment ministers by British environment minister Patrick Jenkin.

The conclusions of the meeting (attended by representatives from Britain, Canada, West Germany, Italy, Japan, the US and the European Commission) were not released at the time, but in a statement following the meeting, Patrick Jenkin said the report of the meeting would stress the "indivisibility of environmental and economic policies". The meeting agreed that there was an urgent need for increased international cooperation on long-term global environmental issues, using existing institutions, which should be given "unambiguous priorities and effective channels for the implementation of decisions". Carl-Dieter Spranger, parliamentary state secretary in the West German interior ministry, told the meeting that his government considered the environment "the most important policy field next to the safeguarding of peace". The West German government, he said, had learned that "a flourishing economy and effective environmental protection are dependent on each other... New low-pollution production processes and environmentally compatible products are a chance of combining the ecologically necessary with the economically reasonable."

Helsinki 1985: The convention is given teeth

The third EB meeting, in Helsinki in July 1985, finally saw the convention given substance. At the second EB meeting in the previous September, work had begun on drawing up a protocol on the reduction of sulphur emissions along the lines of the original Nordic proposal at the first EB meeting. A draft was ready in February 1985, and the protocol — which binds its signatories to a 30% SO_2 reduction by 1993 on 1980 levels (i.e. the same terms as the 30% Club) — was opened for signature at Helsinki. It was immediately signed by the 21 members of the 30% Club, giving it more than enough signatories to bring it into force in October 1985.

Hopes that more countries — including possibly even Britain — might have used the occasion to join the 30% fold came to nought. Britain tamely explained that while it had (by its own calculations) gone much of the way by reducing SO_2 emissions by 25% since 1980, it could not be sure that it would be able to achieve the remaining 5% reduction by 1993. The United States delegation claimed major progress, having reduced SO_2 reductions by 28% between 1973 and 1983, and by 10% between 1980 and 1983; however, it could not sign the protocol because scientific uncertainty made it impossible to design a cost-effective programme of additional SO_2 controls. "While we do not insist on 100% certitude," said Richard Benedick, head of the US delegation, "our policy-makers must have the confidence that any proposed solution will in fact solve the problems of acid deposition." If the weight of evidence ultimately confirmed that further SO_2 reductions were needed "to protect the environment'', he assured the conference, the US would consider ''additional measures'', including a retrofit programme.

Poland — while admitting that sulphur concentrations and transboundary fluxes had increased — argued that the technology needed to control emissions would not be available until the 1990s, and suggested that the state of the Polish economy precluded more than the short-term aim of stabilising SO_2 emissions. The second stage (no timetable was given) was a 30% reduction. It could not therefore sign the protocol.

All the countries represented at Helsinki were unanimous in their support of the EMEP programme and of the need to begin work on the next stage in giving the LRTAP convention more substance: a protocol on nitrogen oxides.

A Marshall Plan for the environment?

How far such agreements as the 30% Club or LRTAP convention protocol will go towards solving the problem of acid pollution is uncertain. Two of the biggest sources of emissions — the United Kingdom and the United States — have consistently distanced themselves from any meaningful commitments to do anything about the problem. Poland — the third largest source of East European emissions (after the USSR and East Germany) — has ratified the convention but has said that for economic reasons there is very little chance of it being able to reduce its emissions.

Reducing air pollutants is still regarded as a sacrifice involving heavy expenditure and hampering economic development and growth. Not until the costs of environmental damage can be counted in hard monetary terms (for example through its effects on trade balance or GNP, or as a cause of unemployment), will there be a real understanding of the need for emission reductions. The traditional debate about environmental protection versus jobs (which is usually argued as an issue of 'either/or' rather than 'both/and') is still frequently quoted.

An approach suggested by West Germany and raised in a 1984 debate by Sweden's Centre Party may need serious consideration, viz. a new 'Marshall Plan' by which wealthier countries would give financial support to those who claim they cannot reduce their emissions due to lack of funds. This could take the form of an international fund from which countries could get favourable loans or similar subsidies to finance emission controls. The Swedish government has rejected the idea on the grounds that it is contrary to the 'Polluter Pays Principle' widely adopted within the OECD. The issue of a fund was nevertheless raised again at a Nordic Council meeting in March 1985 by centrist parties, and resulted in a formal request to the Nordic governments to consider the option further.

Controlling pollutive emissions is not merely a question of percentages or technology, but a fundamental question of balancing economic growth and development against the cost of such irreplaceable natural resources as healthy soil, clean water and air, and plants and animals. The pursuit of material gains may be slowly undermining long-term, sustainable living. In this, developed countries have much to teach the Third World, now in the process of repeating many of the mistakes made by the countries that launched the Industrial Revolution.

Chapter 5

Scandinavia: the first warnings

Every western European country is both a source and a recipient of acid pollution. But some, like the UK, are net exporters, while others, like Norway and Sweden, are net importers. The first signs of acid deposition were identified in western Europe. The concentration of industry and major urban population centres in a compact landmass has made acid pollution a particularly critical issue, and western Europe has become a major testing ground for political initiatives to control emissions and achieve international agreement on tackling transboundary pollution.

Sweden and Norway were among the first countries to diagnose acid pollution damage. Situated downwind from Europe's major industrial centres, they have been on the receiving end of acid pollution for decades, and have been among the most active proponents of international action to control it. Scandinavian concern about acid rain was the spur to the 1972 Stockholm conference, and equal concern about the lack of real progress was the spur to the 1982 Stockholm conference on acid rain.

Sweden, Norway and Finland have thin soils with poor buffering capacity, are well endowed with lakes, rivers and forests, and receive much of their precipitation as snow. Acid damage was first identified in Scandinavia in the 1960s; since 1982 the level of damage in Sweden and Norway has worsened, and damage has been reported from Finland. Forests are a major economic resource in all three countries. As the source of much of Europe's pulp and paper, they have been called "Europe's woodshed"; West Germany and the UK are particularly dependent on Scandinavian forestry deliveries.

All three Scandinavian countries are net importers of air pollutants. In 1982, more than half their sulphur deposition came from foreign sources. All three countries have undertaken, or are planning, substantial reductions in their own emissions (partly to solve domestic pollution problems and partly to set an example to other countries), but there is a limit to how much domestic controls can achieve. Sweden and Norway have argued that reductions under the 30% Club should be regarded as the first step towards really substantial SO_2 and NO_x reductions, and plan to meet the goal much earlier than 1993. Norway is pressing for international acceptance of a goal of 50% reduction of SO_2 emissions in 10 years.

		1980	1985 (Est.)	1995 (Est.)	Reduction (%) (1980-85)
FINLAND	SO_2	595	535	550	7.5
NORWAY	SO_2	137	90	—	—
SWEDEN	SO_2	496	309 (1983)	298	40.0
	NO_x	324	300	200	38.0

Figure 6. Present and estimated future SO_2 and NO_x emissions in Scandinavia (in '000 tonnes). Source: UN Economic Commission for Europe.

The international character of the automobile industry has made it difficult for the Scandinavian countries to act alone on regulating car exhaust emissions. The Swedish car industry has demanded that Sweden wait until the rest of Europe has taken action. Changes in West German policy have been welcomed by the Scandinavians, and an ad hoc working group — made up of representatives from Finland, Norway, Sweden, Denmark, Austria, Switzerland, West Germany, the Netherlands, Canada and Lichtenstein — is currently working out the technical details for the introduction of unleaded petrol and catalytic converters in the ten countries. Much depends on the strength and political will of West Germany to put pressure on its European Community partners.

All three Scandinavian countries — including Norway, with North Sea oil of its own — are trying to reduce their dependence on imported oil (see Figure 7). Sweden derives about two-thirds of its electricity from sulphur-free hydroelectric power, but is planning a moderate introduction of coal and continuing to build its nuclear power capacity until its nuclear power industry is shut down completely in the year 2010. Norway is planning to expand its hydroelectric potential, and Finland is increasing its use of coal, nuclear power and hydroelectric power. All three countries have energy conservation programmes; Swedish energy consumption for domestic and commercial heating has been cut by half since the start of its conservation programme in 1976.

Sweden plans greater future reliance on coal. New legislation on coal combustion was adopted early in 1984 that requires all large installations to fit efficient flue gas desulphurisation (FGD) equipment. Two FGD plants are now in operation, and another five are planned. For smaller plants, where FGD is not economically feasible, emissions standards require the use of fluidised beds or other advanced combustion techniques, or the use of low-sulphur fuels. Economic incentives (including government grants of up to 75% of the installation costs) are being used to encourage the implementation of emission controls.

Sweden. Sweden receives about 58% of its sulphur from Britain,

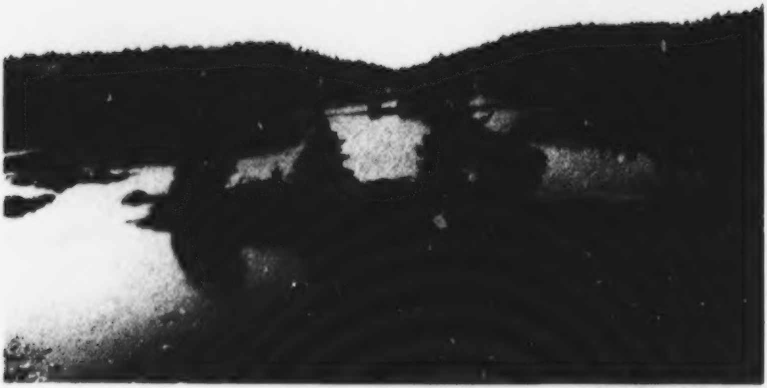
	NORWAY		SWEDEN		FINLAND	
	1980	*1990 (Est.)*	*1980*	*1990 (Est.)*	*1980*	*1990 (Est.)*
Solid fuels	6%	6%	10%	20%	32%	35%
Liquid fuels	38%	33%	52%	31%	48%	37%
Natural gas	4%	4%	6%	1%	3%	3%
Hydroelectric	52%	58%	26%	24%	10%	13%
Nuclear power	—	—	12%	21%	6%	13%
Others	—	—	—	3%	—	—

Figure 7. Energy structure — Norway, Sweden, Finland — 1980-90.

Belgium, the Netherlands, East and West Germany, Poland and the USSR and other industrial centres. The last Ice Age left it with thin soils and little natural buffering capacity, making large parts of the country sensitive to acid damage. Deep concern for the future of forestry, agriculture and human health has prompted Sweden's active role in international emission control initiatives.

Sweden has about 23 million hectares (57 million acres) of forest, largely coniferous. Forest products are Sweden's largest source of export earnings, accounting for 25% of total earnings and for about 100,000 jobs. The bulk of forestry exports (85%) go to Western Europe. Reports of Swedish forest damage in the summer of 1983 prompted a systematic (but still inadequate) inventory by the Swedish Board of Forestry in the autumn, which revealed damage in the south and southwest, the areas with the highest incidence of air pollution deposition from Europe. No precise data about the area damaged were available, but even the preliminary results of the first limited survey indicated that 240 forest stands in 11 counties were damaged, more than half of them extensively (every tenth tree damaged or dying). Damaged trees were more common in old forests. Damage was greatest on the western and southwestern edges of forests — pointing to air pollutants as the cause — and increased above altitudes of 100 metres (330 feet).

In 1982, there were 18,000 acidified lakes in Sweden (twice as many as in 1975), signs of groundwater acidification in parts of western Sweden, and warnings (since confirmed) of future forest damage. Acidification damage has recently been identified in northern Sweden's mountain areas. In the winters of 1979-80 and 1983-84, snow in the far north of these regions was acid, and sensitive waters were damaged. Recent estimates show that some 90,000 km (56,000 miles) of running waters have pH values low enough to cause ecological damage. Sulphur is the main cause of surface water acidification in Sweden. Even if sulphur deposition was



Mark Edwards/Earthscan

Southwest Sweden. There are more than 18,000 acidified lakes in Sweden. Most are so far gone that before they can be rehabilitated, the amount of sulphur entering them will have to be cut by 70-80%.

reduced by 30-50%, it would be insufficient to protect these sensitive waters. A reduction of 70-80% would be needed in the southern parts of Sweden to do any good.

Sweden has reduced its SO_2 emissions by 50% since 1976, at an annual cost of about $100-120 million (mainly the cost of buying low-sulphur oil instead of 2.5%-sulphur oil). Its emission levels are now the same as in the 1950s. The first restrictions were introduced in 1969, but more comprehensive measures came into force in 1976, including use of low-sulphur oil (1% sulphur is the maximum limit), reduced industrial emissions, and energy conservation. A government-appointed group has recently proposed another 5% SO_2 reduction in addition to that already agreed (bringing the total to 65% during 1980-95), and a 30% reduction of NO_x emissions by 1995. NO_x accounts for 30% of the acid in Swedish deposition, and is particularly critical in acid surges during the spring snowmelt.

Groundwater acidification has recently become an issue of major concern, particularly as 3.7 million people (close to half the population) draw their daily drinking water from groundwater supplies, whether directly or through waterworks. Another two million Swedes rely on groundwater at their rural cottages, where many spend the summers. In the worst affected areas (southern and southwestern Sweden), copper piping in water systems has corroded. Annual costs due to acid groundwater and consequent erosion of pipes has been estimated to be as high as one billion Swedish crowns ($120 million). [49]

Norway. The proportion of imported sulphur in Norwegian air (63%) is among the highest in the world, and Norway's domestic SO_2 emission figure of 137,000 tonnes (1980) is one of the lowest in Europe. The UK is the source of 18% of the sulphur. Norway's mountainous west coast is a major factor in the destructive power of Norwegian acid rain — prevailing westerly and southerly winds meet daily with low pressure weather systems, producing rainfall that scavenges pollutants from the air. [50] Norway receives levels of acid pollutants comparable to the most heavily polluted industrial regions of Europe, with the added complication that its granite bedrock — like that of Sweden — has little neutralising capacity.

Half of Norway's precipitation is in the form of snow, which creates particularly critical problems during the spring snow-melt. The snow-melt of 1975, for example, killed large numbers of fish in southern Norway's Tovdal River. Recent studies reveal that fish populations have been lost in 2,650 lakes in an area of 33,000 sq km (1,300 sq miles). Salmon have gone from most of southern Norway's rivers, and brown trout populations have declined, with marked consequences for the popular sports fishing industry. The first signs of forest damage have also been found in southern Norway.

Most of Norway's domestic sulphur emissions come from the combustion of coal and oil in industry, domestic heating and smelting. Almost all Norwegian electricity is generated by hydropower. Legislation introduced in 1961 required all fuel oil to have a sulphur content of less than 2.5%. This has since been reduced in some municipalities and in new sources to 1%. The Norwegian government is considering the long-term introduction of FGD, and has actively helped existing sources to control pollution by offering long-term loans and tax concessions. But with so much of its sulphur imported, Norway argues that there is little more it can do domestically to control acid pollution. Indeed, Norwegian industrialists have in the past resisted strong sulphur controls as expensive tokenism. [51] Hence Norway's active role in international initiatives.

Finland. Finland is the most heavily forested country in the world: about 70% (23 million hectares/57 million acres) of the country is forested, mainly with coniferous trees. Forest products account for 53% of Finland's export earnings and for more than 500,000 jobs.

Acid pollution has only relatively recently become a public issue in Finland. Finland was, for example, one of the last European countries to pass clean air legislation (in 1982). Barely any scientific surveys have been made of the effects of air pollution. But a 1984 survey — the first of its kind — revealed acid damage in a number of lakes near Helsinki; 107 lakes were investigated and half of them — mostly small forest lakes — were found to be either suffering from severe acidification or to have such a low buffering capacity that all their fish would be gone within a year. Lakes with a pH of 4.5 are already devoid of fish, just as in Norway and Sweden, and high aluminium concentrations have also been found. The lakes in the survey were subject to some Finnish industrial and urban emissions, but most of Finland's sulphur (55%) comes from Europe, including Sweden; southeastern Finland receives pollution from the Leningrad area.

There have been no comprehensive surveys of Finnish forests, but damage has been found in the southern and southwestern parts of the country. Researchers at the University of Helsinki and Oulu University are currently investigating atmospheric pollution trends, the sensitivity of pine seedlings to pollution, and the effects of SO_2 on pine needles. If air pollution levels continue unchecked, widespread forest damage is predicted for the 1990s. [52]

Chapter 6

West Germany: the poacher turned gamekeeper

West Germans regard the German fir almost as a national tree, the Christmas tree sung about in Christmas carols. In 1981, the West German government still denied that acid deposition was a problem. By 1985, shocked by the news that three out of four Tannen are damaged or dying and that the species is close to extinction, West Germany was acting vigorously to stave off 'Waldsterben' (forest death), and has become one of the most vocal supporters of European Community action to control acid pollution. (The German fir is correctly known as the Norway spruce, *Picea abies*, and grows across Europe from the Alps to Scandinavia, the Balkans and the USSR.)

"For a German it is simply not imaginable what the world would be like if the forest disappeared" notes Rainer Wehse, a Göttingen University authority on German fairy tales, which are typically set in friendly, shadowy glens. "More than just trees are dying in the Black Forest", reported the *New York Times* in May 1984. "As fir needles turn yellow and spruce branches sag limply, the industrial poisoning of West Germany's forests is assuming the dimensions of a spiritual, as well as an environmental catastrophe." West Germans have long regarded the forest as a refuge from urban life. "The news that the trees are dying has lent West Germany's political debate fresh apocalyptic tones", the *New York Times* noted. "Forest angst blends with fears about nuclear war."

As late as 1981, the West German government still ignored Scandinavian charges that West German pollution was killing Scandinavian lakes. But the growing influence of the Green party (the Greens) and revelations that the damage to West German forests was spreading combined to produce a remarkable and rapid about-face in government policy in 1982. At the Stockholm acid rain conference in June 1982, West German Interior Minister Gerhart Baum called on all states to fight air pollution at source. West Germany undertook to halve its SO_2 emissions by 1993, and has gone on to champion emission controls more vigorously than any other European state.

By 1984 the Federal Ministry of the Interior was warning that economic damage of several thousand million Deutschmarks per year would result if damage to forests continued to spread. As well as the loss in terms of the irreplaceable ecological importance of forest, the loss of the recreational value could have serious economic consequences. The remarkable change in West German government attitudes is confirmed by the fact that one of the most active campaigners against acid pollution is the present right-wing Interior Minister, Friedrich Zimmermann. The debate has become so emotional that Zimmermann himself has been warning against a panic reaction.

Not everyone is convinced that acid deposition is a problem. The Confederation of German Industry claims that existing emission controls are sufficient and that the recent revelations may turn out to be a false alarm. Franz Josef Strauss, minister-president of Bavaria and a former candidate for the West German chancellorship, believes that trees can become used to acid rain. Professor Bernhard Ulrich of the University of Göttingen, the first to identify the role of acid deposition in the death of woodland in the Harz mountains, admits that not all the links between acid pollution and dead trees are perfectly understood. There is general agreement that damage to West German forests is caused by an interplay of several different factors (including air pollutants, frost, drought, injurious insects and fungi) and that the influence of different factors can vary locally.

Forests. Damage caused to German forests by air pollution was recorded in the 19th century. Known as 'smoke damage' because it was particularly visible in areas close to firing and industrial plants, it was found to result from flue gases. Fir dieback has been recorded for over 200 years, and has occurred periodically within central Europe. The damage occurs mainly on the fringes of fir tree forests. During the 1970s, and particularly since 1976, there have been new forms of damage, initially reported on sensitive firs in the south. An outbreak of fir dieback in 1972 was followed by more severe damage in the drought year of 1976. More recently, dieback has been found in spruce beech, and damage has been reported to oak, maple and ash.

Discussion of which species of conifer are affected in Germany is complicated because botanists use the terms 'fir', 'spruce', or 'pine' for distinct groups of species, while non-botanists often use all three terms interchangeably to mean any common conifer. Since many terms are translated from German by non-botanists, the possibility of confusion is increased.

"There has been a drastic increase in the amount of damage to forests in the Federal Republic", noted a 1984 Ministry of the Interior report. [53] "The new type of damage cannot be categorised according to previous experience. It occurs in areas distant from emission sources and, in the case of fir trees, damage has been reported from the centre of their range of distribution. Since then, all tree species have been affected." The report noted that of the total forest area affected, 73% of the damage was slight (trees ailing), 25% was moderate (ill), and 3% was bad (very ill to dying).

Pete Addis

Damaged Norway spruce in the Black Forest. The number of damaged trees in West Germany grew almost sevenfold between 1982 and 1984, alarming the West German government into campaigning more vigorously for emission controls than any other European government.

Its findings were based on a nationwide survey in 1983 which concluded that 2.5 million hectares (6.2 million acres) of West German forests were affected (34% of the total). This was a dramatic increase on the year before, when a survey revealed that 7.6% of forest land was damaged. Forests cover about 30% of the land area of West Germany, and consist of about 70% conifers and 30% deciduous trees. The 1983 survey found that 76% of the silver firs were damaged, 41% of the spruces, 43% of the pines, 26% of the beeches and 15% of the oaks.

The news has since become even worse. A survey in mid-October 1984 found that 50.2% of West German forests were affected by air pollutants. Had the summer of 1984 been hotter, the figure would probably have been even higher, since hot, dry weather promotes the spread of damage. Of the older trees (more than 60 years old), 82% of the firs and spruces (of which the silver fir is almost gone) and 73% of the pines, 50% of the beeches and 43% of the oaks are now damaged. More trees than are normally allowed to be felled in one year have had to be classified as dead or dying and taken away.

In the central and southern states where the largest forested areas are found and where forestry has the greatest economic and aesthetic value, the damaged area has nearly doubled since 1983. The situation in Baden-Württemberg and Bavaria is particularly serious: 60% — and in some areas 85% — of the trees are now severely damaged. In the Bavarian alps nearly 70% of the trees are dying, leading to warnings that alpine forests will have lost their capacity to prevent avalanches within 5-10 years.

Other ecological changes — soil erosion, rainwater runoff, and disruption to wildlife — will follow. High levels of heavy metals have been detected in Bavarian groundwater. Damage to forests over large areas occurred initially in older forests in higher mountain areas. Since then, younger trees and forests in low-lying areas have been increasingly affected. The trees have lost their vitality and resistance, and have become more prone to pests, and to damage by wind, snow and drought.

The forests suffering the most serious damage are those in the South German low mountain ranges, particularly in the East Bavarian border area and the Schwarzwald (Black Forest). Severe damage has also been reported in other mainly mountainous areas such as the Harz, Sauerland and Eggegebirge.

The economic implications of forest damage and dieback are alarming foresters. The timber market may be disrupted by uncertainty over the quality of the timber from damaged forests. West German foresters are taking the lead in the campaign against air pollution, but at the same time, they want to avoid speculation about timber quality so that prices do not fall. There is also the risk of heavy dumping of 'second rate' timber, which would lower the prices further. The Union of German Forest Owners' Association estimates that losses as a result of forest damage already a — energy consumption by fuel

	1980	*1990 (Est.)*
Solid fuels	30%	31%
Liquid fuels	48%	39%
Natural gas	17%	18%
Nuclear power	4%	12%
Hydroelectric and others	2%	1%

b — sources of emissions

	SO_2		*NO_x*	
	1970	*1982*	*1970*	*1982*
Power stations, district heating plants	45.9%	62.1%	26.5%	27.7%
Industry	32.3%	25.2%	25.5%	14.0%
Households, small consumers	18.6%	9.3%	6.0%	3.7%
Motor traffic	3.2%	3.4%	42.0%	54.6%

Over 40% of the total energy requirement is used in domestic space and water heating.

Figure 8. Energy structure and air pollution in West Germany.

amount to about $400,000 per year. The premature felling of damaged timber can still be contained within normal long-term felling plans, but felling could soon seriously affect the timber market. The Ministry of the Interior believes that after a transitional phase of timber surplus, loss of growth and long-term scarcity of timber with all its associated consequences for income and employment in the forestry and timber-processing industry, could well be a reality.

Acid winds over the Harz. The Harz, near the border with East Germany, is a forested mountain area popular with hikers and skiers, containing nature reserves and health resorts. It was regarded as one of the cleanest regions in West Germany; people visited the Harz for the pure, reviving air; there are no industries or other evident sources of pollution. But 200 kilometres (125 miles) to the west is the Ruhr, the industrial heartland of West Germany, with its massive emissions of gases, carbon compounds, metals and particles. This is carried by westerly winds to the forests, soils and waters of the Harz.

Fifteen years ago there were no visible signs of damage in the Harz. Today damage is spreading rapidly. Land above 600 metres (2,000 feet) is already seriously affected, and evidence of damage is spreading to lower land. Large areas of forest are dead or dying from nutrient deficiency, aluminium poisoning, dying roots and impaired vitality. Trees knocked over by the wind — which need not be very strong — reveal abnormal root systems. The trees have tried, in a last attempt to survive, to stretch their roots out in the humus layer of the soil, just below the surface, in order to avoid the toxic metals in the soil water. It takes only a light wind or short cold or dry periods to kill a tree with so little natural strength left.

The Harz area is an important freshwater reservoir for northern Germany. Artificial lakes have been dammed to provide Hamburg, Bremen, Hanover and other cities and towns with water. The water is still drinkable, because the buffering systems in the ground can still neutralise most of the acidic deposition, but the buffering capacity is becoming weaker. Little decomposition takes place in the soils of the Harz. Dead trees, branches and twigs lie largely unaffected on the ground. Only spruce bud worms really like it in the Harz. They come in large numbers and find excellent living and reproduction conditions. They will eventually pose a threat to the forest that is still alive, further down the mountain slopes.

The Harz is badly affected, but the situation is even worse in southern Germany: the Fichtelgebirge and Bayerischer Wald in Bavaria, and the Schwarzwald in Baden-Württemberg are particularly seriously affected. The position is only slightly better in the rest of the Bavarian and Baden-Württemberg forests. Also affected is the Böhmer Wald (Bohemian Forest) on the West German/Czech border, and the Erzgebirge, on the East German/Czech border.

Watercourses, lakes and groundwater. Surveys in 1981-83 found far higher acid levels than usual in the unpolluted upper reaches of free-flowing waters with low lime content, particularly in the upland areas of lower mountain ranges. In some cases, levels are higher than those found in Scandinavia. Acid levels in watercourses in the Bayerischer Wald and the northern Schwarzwald are comparable to values found in Sweden; in the southern Schwarzwald the values are lower, similar to those found in southern Norway. High aluminium concentrations have also been found in these watercourses.

No comprehensive evaluation of lakes has yet been made, but sediment tests and other studies have shown that acidification is concentrated mainly in the Bayerischer Wald, the Fichtelgebirge and the northern Schwarzwald. Acidification has even been reported in naturally acidic moor ponds and heath lakes, where pH values have fallen by one to two points since the 1950s. The quality of groundwater has not been thoroughly surveyed, but there is evidence of high levels of heavy metals in Bavarian groundwater, and acidification of water in the Taunus and Hunsruck mountains.

Buildings and monuments. Serious damage to buildings and structures — caused at least partly by air pollution — has increased steadily over the past 30 years. The steel in the Hamburg television tower is rusting.

Pete Addis

Cologne Cathedral, West Germany. Acid damage to West German buildings has spread rapidly in the last 30 years. The sandstone on Cologne Cathedral is decaying; $1.5 million is already being spent every year to try and control the damage to stonework and stained glass windows.

The sandstone in Cologne Cathedral is decaying. The cost of preserving the cathedral and its stained glass windows already runs to $1.5 million per year. On that basis, the estimated cost of preserving and renovating the country's architectural and artistic monuments is conservatively estimated at well over 300 million DM (US$90 million).

According to the Ministry of the Interior, the annual cost of damage to selected categories of property amounts to about 3-4,000 million DM (US$900-1,200 million). A 37% reduction in SO_2 emissions, costing around 1,000 million DM (US $300 million) would reduce the costs of pollution damage to galvanised and coated steel alone by 600 million DM (US$ 180 million).

Reducing emissions. Annual SO_2 emissions in West Germany were believed to be 3.2 million tonnes in 1980. New legislation was passed in 1983 (the 1983 Ordinance on Large Combustion Installations) aimed at halving SO_2 emissions by 1993. The ordinance applies only to power stations with a capacity of more than 50 MW. About 1,500 installations come into this category.

Despite its aims, the ordinance has already created controversy because of its exemption of power stations already planned or under construction. The coal-fired power station at Buschhaus, near Helmstedt, in Lower Saxony (not far from the Harz area) began operating in April 1985. It was built less to supply the region with electricity than to secure jobs and utilise local supplies of lignite, a form of soft coal with a high sulphur content (3.5% compared with the 1-2% sulphur content of brown coal).

Buschhaus was classified as an existing plant as it was already being built when the new ordinance entered into force, so there were fears that it would not be forced to take measures to reduce its emissions until 1987-88, and could begin operating without a desulphurisation unit (which would have cost US$60 million). Its chimney is 307 metres (1,005 feet) high and it will emit 125,000 tonnes of SO_2 per year, or 18 tonnes of SO_2 per hour.

The Federal Association of Citizen's Action Groups for Environmental Protection (Bundesverband Bürgerinitiativen Umweltschutz e. V.) described Buschhaus as "a European problem. We see the 307-metre high chimney as a symbol of political irresponsibility to other Western and Eastern European nations. Buschhaus is a test for the seriousness of declarations by many European governments to give priority to measures for improving air quality."

The Greens and the SPD (Social Democrats) managed in the spring of 1984 to make the Bundestag (the federal parliament) agree that the government ought not to allow the opening of Buschhaus until a desulphurisation compromise was agreed. Buschhaus would then initially be allowed to use only brown coal, and only one of the two units of the plant would be opened, at least for the time being. By making these changes the emissions would be reduced from 145,000 tonnes to 125,000 tonnes per year. It was also agreed that the unit in operation should install desulphurisation equipment from 1986, thereby reducing emissions to 35,000 tonnes by 1987.

West German scientist Dietrich Soyez, commenting on the new ordinance and the transition regulations for older plants, commented that it was "a programme approved by the government to do away with the coniferous forests of Germany". City authorities, foundations and forest owners have considered suing the Federal Government for "not stopping the expropriation of land through long-range transport of harmful pollutants".

Curbing vehicle emissions. "Autobahn speed limits arouse the same kind of passions in West Germany as gun control laws do in the United States", noted the *New York Times* in 1984. The bulk of West German motorists, supported by the power of the West German automobile industry, regard any attempts to impose road speed limits as an infringement of personal liberties. The slogan 'Freie Fahrt für freie Bürger' (Free speed for free citizens) encapsulates West German attitudes.

The speed limit issue was first raised by environmentalists when it was apparent how badly damaged the forests were. With 85% of the country's forest now acid-damaged, the issue has become central to attempts to control acid emissions. Responding to pressures from the environmental lobby, the Ministry of Transport announced in late 1984 that an experimental speed limit would be imposed on 20 test stretches of road throughout the country in an attempt to find out whether lower speeds would significantly reduce pollution. The first — on a 40-km (25-mile) stretch of autobahn between Hamburg and Bremen — was imposed in January 1985. For a period of nine months, cars are being restricted to 100 kph (62 mph), and the results will be evaluated in November 1985. The volume of traffic was to be measured and driving behaviour noted before and after the imposition of the speed limit. Environmentalists have dismissed this as pure theatre, charging that it will prove little.

West Germany has been more active recently than any other European nation — except Switzerland — in promoting regulations on car exhaust gases. NO_x and hydrocarbons are central to the problem of forest damage and forest death in West Germany, so any strategy to solve the problem must include a substantial cut in motor vehicle exhaust emissions. But it will also mean taking on the powerful West German car industry.

West German measures will also raise a number of international problems. In the summer of 1983 the West German government announced that it intended to introduce unleaded petrol and catalytic converters in order to reduce NO_x, hydrocarbon and lead emissions. The introduction was originally planned for 1 January 1986, using a combination of legislation and economic incentives (lower prices on unleaded petrol, and reduced taxes on cars with catalytic converters). But the proposals triggered off massive protests from the other car-producing EC countries. Italy and France were quick to reject the idea, as was the UK.

West Germany then changed its proposals, and decided to introduce tax incentives from 1 July 1985. Mandatory regulations on catalytic converters will enter into force in 1988 for large cars and in 1989 for smaller ones. Nevertheless, filling stations supplying unleaded petrol have been set up throughout the country, notably on autobahns where 260 filling stations were being refitted with effect from mid-1984.

Ironically, the proposed speed limits would probably make all the difference in the areas most severely affected by direct and indirect damage from NO_x, ozone and hydrocarbons. Introducing catalytic converters would mean effective cuts in emissions, but not until the early 1990s. A reduction of autobahn speed limits from the present 'free speed' limit to a maximum 100 kph (62 mph), would, according to recent calculations made by the Berlin environment agency (Umweltbundesamt), reduce West German NO_x emissions by 185,000 tonnes per year (6%).

Past West German governments have promised not to tamper with the speed limits, but the new, even more alarming figures on spreading Waldsterben in West Germany may change the government position.

Chapter 7

Britain: Still outside the fold

Britain is the biggest emitter of sulphur dioxide in Western Europe, and the fourth biggest in the world. Despite mounting evidence in 1982-85 of acid damage to British forests, lakes, rivers, wildlife, crops and buildings, and despite mounting pressure on Prime Minister Margaret Thatcher from scientists, European Community governments, pressure groups, and members of her own party in the British and European parliaments to agree to a reduction in SO_2 and NO_x emissions, Britain steadfastly refused to act. By July 1985, the only EC countries that had not yet joined the 30% Club were its two least industrialised members (Greece and Ireland) and one of its most heavily industrialised — Britain. There were growing signs, though, that this reluctance was proving to be a matter of increasing political embarrassment.

Estimates of British SO_2 emissions vary from 4.0 to 5.2 million tonnes. The 1980 EMEP figure is 4.68 million tonnes, which makes Britain second only to the USSR in Europe. Britain also emits about 1.8 million tonnes of NO_x. The major emitters of SO_2 in the UK are fossil fuel power stations. In 1980 the UK derived 94% of its energy needs from fossil fuels (and most of the balance from nuclear power). The Department of Energy forecasts that UK emissions will be proportionately greater than the rest of Europe by 1990, when its emissions are projected to have fallen by less than 5% over 1980, compared to a fall of 60% in West Germany by 1988 and of 30% in many other Western European countries by 1993. Britain also suffers less from other countries' emissions than most of its European neighbours (and, conversely, is responsible for most of its own acid deposition); a 1984 government report suggests that other countries account for as little as 11% of all acidity in British rainfall.

The British government view has traditionally been that not enough is known about the causes of acid pollution and that substantive action is inadvisable until the link is firmly established. But, notes Britain's Earth Resources Research group, this is likely to be seen as "obdurate self interest rather than commendable caution". [54] Before 1982, the UK and West Germany were agreed in their rejection of Scandinavian arguments about the effect of airborne pollutants. The West German turnabout has left Britain alone in Western Europe.

The current British position was outlined in July 1985 by environment

		SO_2		
	1972		*1982*	
	thousand tonnes	*%*	*thousand tonnes*	*%*
Power stations	2,870	51	2,650	66
Other industry/agriculture	1,750	31	760	19
Refineries	260	5	210	5
Domestic	370	6	200	5
Commercial/public service	310	5	170	4
Road transport	60	1	50	1
Rail transport	20	>1	10	>1
TOTAL	5,640	100	4,050	100

		NO_x		
	1972		*1982*	
	thousand tonnes	*%*	*thousand tonnes*	*%*
Power stations	731	42	769	46
Road vehicles:				
petrol engined	262	15	318	19
diesel engined	158	9	172	10
Commercial and industrial	470	27	309	19
Domestic	51	3	51	3
Railways	48	3	35	2
Incineration and agric. burning	8	>1	12	>1
TOTAL	1,728	100	1,666	100

Figure 9. Sources of SO_2 and NO_x in the UK. Source: Warren Spring Laboratory, Department of Trade and Industry.

minister William Waldegrave, speaking in Helsinki at the third meeting of the LRTAP convention executive board. Britain, he said, counted itself among the countries committed to reducing SO_2 and NO_x emissions; it had reduced SO_2 emissions by 42% since 1970, and by 25% since 1980, by using lower sulphur fuels, by using energy more efficiently, and by 'industrial restructuring' (a phrase interpreted by the government's critics as 'industrial recession'). Further reductions of SO_2 and NO_x are planned, aimed at a reduction on 1980 levels of 30% by the end of the 1990s (Mr Waldegrave hinted that expanded nuclear energy capacity would be one factor in the continued reductions).

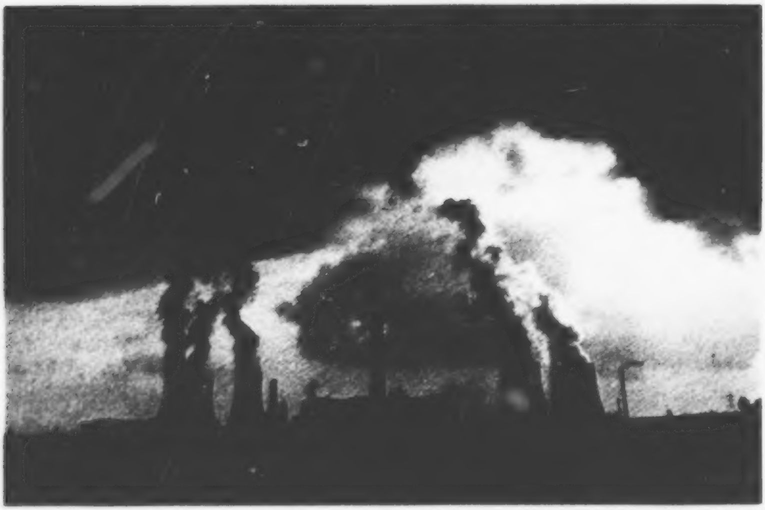
Britain could not sign the LRTAP convention protocol on SO_2, said Mr Waldegrave, because "we cannot be absolutely certain about the likely change in our sulphur dioxide emissions over the next decade", and because Britain was not absolutely certain that it could meet the target of a 30% reduction by 1993. "It may well be", he said, "that even though we are not able to sign [the SO_2 protocol], our actual performance will be equal to or better than that of a number of countries that do". Privately, some British officials felt that Britain's decision not to sign the protocol was more honest than that of countries which had signed with little certainty that they would actually be able to achieve a 30% reduction by 1993.

Mr Waldegrave spoke of the confusion caused to British calculations by the effect on SO_2 emission figures for 1984 of the coal miners strike, and by the need to await the outcome of a public enquiry on a major new nuclear power station planned for Sizewell in Suffolk. Britain also regarded the terms of the SO_2 protocol as "arbitrary"; while emissions from some other countries had risen during the 1970s, Mr Waldegrave argued, Britain had made a "significant contribution" to SO_2 reductions in Europe; if the terms of the protocol had been a 40% reduction on the year of peak emissions, Britain would already have met that condition.

The energy lobby

The two major actors on the British stage are the National Coal Board (NCB) and the Central Electricity Generating Board (CEGB). The CEGB is Britain's largest electricity producer, the NCB produces virtually all the country's coal. The CEGB is in turn the NCB's largest consumer and accounts for 80-90% of Britain's electricity supplies. CEGB power stations emit about 60% of the UK's total SO_2 emissions. NCB chairman Ian McGregor has claimed that the UK "does not make a major contribution to sulphur dioxide emissions — less than 7% of the total for Europe (including the USSR) in fact — and has reduced the amount by more than 30% over the last 12 years. The total European emissions increased from 1965 to about 1972 but depositions in Scandinavia reduced during the same period." On Britain's reduction in emissions, he was correct. SO_2 emissions fell by 37% between 1970 and 1984 — not through pollution control measures, but because of production cutbacks in the wake of the industrial recession, and the increasing use of sulphur-free natural gas (which now supplies more than 20% of the UK's primary energy).

Mr McGregor argued that remedial action forced upon energy producers could be so expensive that energy costs would rise, reducing their competitiveness and affecting jobs. He added: "There is a distinct possibility that after we have crippled some of our basic industries we could



Laurie Sparham/Network

Fiddler's Ferry power station, Merseyside, UK. Emissions from coal-fired power stations help make Britain the biggest emitter of sulphur dioxide in western Europe. Yet fitting controls to just 12 power stations could cut British SO_2 emissions by 60%.

then find we had not solved the problem. If all industrial activity ceased tomorrow there would still be acid rain for natural reasons and there always will be... It would be folly to adopt enormously expensive counter-measures which might in 20 years prove to have been unsuccessful." He was in favour of short-term action — such as liming affected waters — that would give scientists more time to establish the facts. In 1984 he told a House of Lords select committee that EC moves to cut SO_2 and NO_x emissions should be delayed until pressurised fluidised bed combustion technology under development by the NCB and CEGB was ready in the 1990s.

The CEGB for its part points with some satisfaction to the success of its postwar policy of building tall smokestacks (200 metres/650 feet or more in height) in dispersing emissions. This is known to have contributed, for instance, to the reduction of the sulphurous smogs for which London was once infamous (but, as the CEGB fails to observe, has simply distributed the pollution further afield). The CEGB also argues that life was dying in Scandinavian lakes at the turn of the century, well before tall stacks were built.

CEGB chairman Lord Marshall (formerly Sir Walter Marshall) observed in 1983 that a threefold reduction in SO_2 emissions from the UK would probably cost more than £4,000 million, with a continuous ongoing annual cost equivalent to £700 million: "If we consider the whole of Western Europe, these figures rise by at least a factor of five. Since electricity is essential for everyone, this will effectively lower everyone's standard of living and it would be tragic to do this without understanding exactly what we are accomplishing". Britain could in fact cut its SO_2 emissions by 60% by 1995 (as proposed by a European Community directive) by having the CEGB install flue gas desulphurisation (FGD) equipment at just 12 of its power stations. The CEGB has been unclear on the costs involved. In 1980 it said that the cost of fitting FGD equipment to one new 2,000 MW power station was £250 million. In 1983 it put the cost of meeting the EEC directive at £150 million per station. By 1984 it was quoting a figure of £120 million per station, or just over £1.4 billion for all 12. It has also variously put the cost to consumers in increased electricity rates at between 4% and 10%.

In 1983 a £5 million five-year study was launched by the Royal Society, the Norwegian Academy of Sciences and the Royal Swedish Academy of Sciences, with financing from the NCB and the CEGB. The object was to study the impact of acid rain on the soil, waterways and fisheries of Norway and Sweden.

The study was greeted with anger by Scandinavian scientists, who argued that much of the research had already been done, and that the British government was simply buying time. A year into the programme, the British science weekly *New Scientist* reported that only 2% of the budget had been spent and that British and Scandinavian scientists alike were complaining of bias in the way the money was being allocated. There was no procedure by which scientists could apply for grants; instead the committee administering the project itself decided which issues it wanted to investigate. The future of the project is now in doubt.

Official reports

In its 1984 report, the Royal Commission on Environmental Pollution described British pollution control policy as suffering from inadequate resources, secretiveness, isolationism and a lack of forward planning and continuity, and of failing to keep abreast of pressing environmental problems. Three major official reports published during 1984 subjected the policy to even closer scrutiny.

The first [55] — compiled by the government's Warren Spring Laboratory at the request of the Department of the Environment — was described by Friends of the Earth (FoE) UK as "a masterpiece of equivocation", but it did nevertheless add much to the picture of acidification in Britain. The report dealt mainly with measurements of acidity in rainfall in Britain, and drew few conclusions about its possible adverse effects. It did however reach the following conclusions:

- Britain's rain is acid-polluted: it is commonly 100-150 times more acid than unpolluted rain, and in one case (at Bush, Scotland) more than 600 times more acidic than normal. Sulphur accounts for 70% of the acidity in British rainfall, and nitrates for the remaining 30%; areas at greatest risk include Cumbria and the west central highlands and southern uplands of Scotland.
- Other countries account for only 11% of all acidity in British rainfall; much of the deposition in northwest Britain may originate in Europe.
- Acidity comes in short bursts (for example, 30% of the acidity in rain falling at Goonhilly in Cheshire in 1980 fell in just five days (2.7% of all wet days) with 50% falling in just 10 days).
- Urban areas may suffer significantly higher acidities, e.g. Glasgow 41%, Nottingham 20% and Norwich 94% in excess (the report excludes urban sites and those near industry from its data base).
- Dry deposition of sulphur, which is difficult to measure because it enters (and damages) plants as fine gas or particles, is up to three times as acid as wet deposition in parts of Britain (especially South, East and Central England). This may acidify wetlands (e.g. new forest pools, bogs) and damage crops.

The second report [56] — by the Environment Committee of the House of Commons — was the most comprehensive. The introductory chapter acknowledged that what acid rain is and what it does are imperfectly understood, hence British reluctance to take action. But the Committee emphasised that it had begun its inquiry with an open mind, and was "now convinced ...that immediate and hard financial decisions have to be taken as time is running out. Simply to plead for more research into cause and effect is but to procrastinate. Enough is now known to justify the development and application of technology for removing the causes and effects now abundantly apparent."

The study noted that despite the 37% drop in British emissions since 1970, the United Kingdom was then, and in 1984 still was, the largest producer of SO_2 in Western Europe. The study pointed out that there was no significant reduction in CEGB emissions during the period when total UK emissions fell (CEGB emission reductions accounted for only 14% of total UK reductions between 1972 and 1982): "If action is to be taken to control the volume of UK emissions, it could therefore be focused largely on this single source". Ironically, the British miners' strike of 1984-85 had the unexpected effect of increasing SO_2 emissions from the UK by an estimated 8,000 tonnes per month. Power stations normally fired by coal switched largely to oil, which has a higher sulphur content than domestic British coal. Scientists at the University of Sussex estimated that British SO_2 emissions from power stations in August 1984 were 18% higher than those of the previous August. [57]

The third report [58] — by the House of Lords European Communities Committee — was published in June 1984 and examined the implications of European Community policy on Britain. It was far more hesitant than the Commons report, criticising the scientific assessments made by the European Commission as the basis for five proposed new pieces of legislation, challenging the Commission's assumption that there was a linear relationship between emissions and deposition, and arguing that the evidence of a link between acid deposition and damage to trees was not as clear as the Commission suggested. The evidence available did not justify the expenditure and "environmental damage" that would result from using FGD to achieve the 60% reduction in SO_2 emissions proposed by the Commission; the Committee favoured the use of pressurised fluid bed combustion (PFBC), although it was "not appropriate" that emissions from coal-fired power stations should continue unabated until PFBC technology was ready in the 1990s.

On the other hand, the Committee acknowledged that acid air pollution was a serious threat, and that it would be "foolish and dangerous" for no action to be taken to combat the problem. "The magnitude of the damage resulting, the length of time over which this might become apparent, and its widespread effects if the fears expressed prove to be justified, make it necessary to implement a preventive programme now, despite the scientific uncertainties." The Committee recommended that at least two CEGB power stations should immediately be fitted with flue gas desulphurisation equipment.

The Committee took the European Commission to task for saying in its directive on emissions from large combustion plants that the 1983 US National Research Council (NRC) report had proved the existence of a linear relationship between emissions and deposition. The Committee pointed out that the NRC study had clearly stated that the relationship in Europe over the previous 25 years had been strongly non-linear, and that reliable evidence on the linear relationship in the United States was based on data from one site. Hence, said the Committee, the Commission had effectively "weakened confidence in its Directive by misrepresenting the evidence on such a critically important issue".

Acid damage. One of the major barriers to encouraging British government action on acid rain is the variable quantity and quality of evidence of acid pollution damage in the UK. Monitoring undertaken in urban centres has revealed a fall in winter concentrations of SO_2 since the 1960s, which is only to be expected in the wake of the construction of taller smoke stacks. But, as the 1984 Commons committee emphasised, there is a noticeable lack of rural monitoring programmes, and no data was available to show if rural levels of pollution had increased since the introduction of tall stacks. The Warren Spring report showed that many parts of rural Britain were not monitored for SO_2, NO_x, rainfall pH or ozone. The Warren Spring Laboratory itself ran only three NO_x monitoring stations. In 1984 — in response to the Warren Spring report — the Department of the Environment announced that 25 new acid deposition monitoring stations were to be established and £750,000 spent on improving existing stations.

Such research programmes as exist are frequently used as an excuse for inaction. In 1983 a Department of the Environment spokesman told *New Scientist* that "as far as we're concerned research is action".

Enough instances of the effects of acid pollution on lakes, rivers, fisheries and buildings have been recorded to indicate that acid pollution is indeed affecting many parts of Britain. The areas at greatest risk are those in which soils or bedrock have limited buffering capacity: notably parts of Wales, Scotland and the Lake District. The Forestry Commission was sufficiently perturbed by the early results of a 10-year research programme by the Ministry of Agriculture, Fisheries and Food (MAFF) to begin liming lakes in Galloway (Scotland) in 1982. According to chemist Stuart Coy of the Solway River Purification Board in southern Scotland, rain with a pH of 4.6 is common in the area, but the acidity can rise quite dramatically in a matter of hours when the wind is coming from the south, where the major urban areas of the Midlands are located. Rainfall with a pH of 3.5 has been recorded.

The 1982 Warren Spring report pointed out that parts of Cumbria (in England), and the West Central Highlands and southern uplands of Scotland were receiving the largest inputs of acidity, and the amount of acid deposited was "of the same order as regions of Scandinavia and North America". The report found that "the very acid rain events were associated with 48-hour trajectories (of wind) over large industrial regions of the United Kingdom and Europe while the very clean rain events were associated with trajectories over the North Atlantic".

In 1983, a report by the director of scientific services for the Welsh Water Authority pointed out that acidification had resulted in many of the upland streams, rivers and lakes draining afforested catchments in Dyfed and Gwynedd (southwest and northwest Wales respectively) becoming unable to support natural fish populations. In the river Tywi in mid-Wales, native brown trout had not been able to survive the combined effects of acidity and increased aluminium concentrations in water draining from conifer forests in the area. The Berwyn catchment in north Wales was too acidic even to support the American brook charr, a fish introduced specifically to cope with the acid. In May 1983, agriculture minister Alick Buchanan-Smith admitted that acidity had adversely affected salmon nursery areas in Cumbria and Wales. The Royal Society for the Protection of Birds reported in September 1984 that acidification of the Wye and Tyne rivers in central Wales, which drain through forested areas and have a higher aluminium level than those draining open moorland, could threaten the survival of the dipper, a freshwater bird.

In 1984 the Nature Conservancy Council (NCC), Britain's statutory conservation agency, voiced its support for the EC draft directive on cutting SO_2 and NO_x emissions from large combustion plants. The NCC observed that a worrying aspect of acidification in Britain was that the most vulnerable areas — such as southwest and central Scotland, the Lake District and the Welsh mountains — included many protected wildlife sites identified by the NCC as key nature conservation areas. It discounted suggestions that afforestation had been responsible for much of the accelerating acidification of upland freshwaters. [59]

Declining catches have been reported by fishermen in Scotland, Wales and the Lake District, and fish losses have been reported by fish farmers in Scotland and Cumbria. The Commons study quotes effects on other animals than fish — such as birds and otters, which suffer when the ecological balance of lakes and rivers is disturbed — and also refers to evidence of forest damage to trees in the Lake District. A survey made at 47 sites in 14 areas by the Scottish branch of Friends of the Earth, with the help of a German forestry expert, concluded that about 65% of the 47 sites showed signs of damage from air pollution; affected species included Scots pine, Norway spruce, Sitka spruce, Douglas fir and hardwoods (beech), all of which can be considered commercial forest species. Areas around the Lake District and the Forest of Dean (South Yorkshire) are heavily affected.

Forestry Commission officials have observed extensive dieback of shoots on Scots pines, evidenced by browning of needles; "Some damage was also observed to Norway spruce and Sitka spruce. A minority were badly damaged enough to be at risk of dying."

The House of Commons study quotes MAFF as holding that there was no evidence of discernible damage to UK agriculture in general, a view the committee considered "complacent and founded upon little other than conjecture". A 1983 EC-sponsored study by Imperial College, London into the effects of SO_2 and NO_2 on the black bean aphid — an important crop pest — found that in addition to any direct damage being done to crops by pollutants, chemical changes induced in plants enhanced the growth of insect feeding on them. [60] Measurements undertaken by Harwell Laboratory in Oxfordshire in 1983 revealed that ozone concentrations rose above levels thought to cause crop damage on 24 days, but only on one day did mean hourly ozone concentrations rise above the air quality limit set in the United States. [61]

The CEGB has dismissed any connection between its emissions and corrosion to buildings, arguing that it would take 5,000-20,000 years to dissolve an inch of limestone. The Commons committee dismissed this response as "trite and evasive". In 1983 the CEGB suggested that it was "well established by international experts that the principal cause of stonework corrosion is high concentrations of gaseous pollutants. These ...occur only in urban areas and are the result of many small sources of pollution with power stations making only a minor contribution." [62] Among the examples quoted by the House of Commons report:

- Over the last 10 years, £5 million has been spent on restoration of the stonework of Westminster Abbey. Much of the damage has been ascribed to SO_2 and other gases. In 1894, 44 flying buttresses on the south face of the abbey were rebuilt in limestone. They now need replacement because of SO_2 damage.
- An architect giving evidence to the Commons committee pointed out that the fact that stones of the 13th, 18th and 19th centuries on Beverly Minster (near Hull, northeast England) have been indiscriminately affected by decay confirms that damaging pollution is relatively recent in the whole life of the building.
- The copper sheeting on the roof of Liverpool Cathedral may have to be replaced. There is evidence of a link between acid rain and the deterioration of the sheeting, which is at its worst at the points where rainwater is longest retained.

The Senior Sculpture Conservator at London's Victoria and Albert Museum, whose department has researched stone decay for 20 years, told the Commons committee that "the problem of decay had accelerated dramatically since the turn of the century; that rural as well as urban areas were affected; that no technology existed to preserve any stone sculpture in an external environment. There is, at present, no method of reducing weathering caused by air pollutants except to reduce the SO_2 levels themselves."

Future British emission policies

Summing up its findings, the Commons committee emphasised that its inquiry had left it "deeply disturbed over the United Kingdom's current policy position on acid rain". Furthermore, "we believe our work demonstrates that sufficient evidence exists to show that the decision to reduce emissions of SO_2, NO_x and hydrocarbons should be taken now". The Lords committee recommended that the UK should aim at reducing

SO_2 emissions by at least 30%. The Commons committee recommended that:

- the UK immediately join the 30% Club,
- the 30% cut in emissions be achieved by requiring the CEGB to reduce its emissions accordingly,
- in the medium-term, as power stations come to be refitted, the CEGB should be required to install the equipment necessary to achieve a *60% national reduction* in emissions by 1995, in line with the EEC draft directive,
- the quickest way to reduce emissions was by retrofitting power stations,
- to help reduce NO_x emissions, all power stations should install low NO_x burners; all industries other than those dependent on high combustion temperatures install low NO_x burners in existing plants; new motor vehicles be required to have reduced NO_x emission levels by 40% by the beginning of 1987; and the Department of Transport investigate the best possible means of reducing emissions from existing motor vehicles.

The CEGB responded to the report by again arguing that the scientific evidence was either dubious or missing, that the measures suggested would raise electricity costs by 10% and increase unemployment. In an editorial comment, *The Guardian* newspaper commented that the CEGB, in suggesting that it would cost £2 billion to reduce emissions, was "trying to scare us". Spread over nine years, it argued, the sum was well within the electricity budget.

Lord Marshall has more recently repeated the CEGB view that cutting sulphur emissions is too expensive and of no proven benefit to the environment. However, he said, acidifying emissions from CEGB power plants would be decreased, and the Board plans to experiment with the reduction of NO_x emissions from some plants by using two-step combustion: the coal is first burned in chambers with little oxygen supply, and the air streams in the boiler are then changed to reduce the formation of NO_x. Some CEGB boilers can easily be rebuilt for the purpose, but the Board claims that it would cost close to £90 million to have all the boilers changed.

The CEGB has shown some interest in obtaining more effective combustion in fluidised beds. Announcing the launch in October 1984 of four research projects aimed at removing SO_2 and NO_x from coal-fired power station emissions, Lord Marshall argued that acid rain was "a woolly definition covering a range of pollutants that require very different control measures... The research we have been doing over the last four years leads us to suspect that cuts in hydrocarbons from vehicles and other oil-burning appliances, and nitrogen oxides, may actually be more important than sulphur dioxide reductions, both for forests and for acid rain... If reductions [in NO_x] would be environmentally cost effective, we would certainly want to be in a position to act, just as we are on sulphur dioxide." [63] In January 1985 the CEGB and NCB began a joint two-year £25 million project to develop an experimental pressurised fluidised bed combustion furnace (the largest in the world), but commercial application before the late 1990s was thought to be unlikely.

Britain is also unwilling to commit itself to reducing vehicle emissions. In March 1984 the Department of Transport argued that catalytic converters then available "would worsen fuel economy" and add about £2 billion per year to motoring costs and that "such expenditure is not justified to deal with emissions from petrol-engined vehicles in the UK". [64] British motor manufacturers promised in 1979 to work towards reducing petrol consumption on new cars by 10% by 1985, a target that was passed and exceeded in 1983, mainly through the development of high compression 'lean-burn' engines. They argued then that savings as high as 17% would have been achieved but for the terms of EC directives on emissions reductions, and maintain that lean-burn technology reduces NO_x emissions. This is true, but the reductions possible with catalytic converters are believed to be greater.

The British government rejected the joint recommendation from the two Houses of Parliament to cut SO_2 emissions in the UK, refused to support the EC directive on SO_2 and NO_x emissions, turned down the proposal for a £1.4 billion ($1.7 billion) project to reduce emissions from 12 British power stations and refused to join the 30% Club. The only recommendation accepted from the Commons committee report was the need for further monitoring and research. The committee chairman, Conservative Sir Hugh Rossi, called the government's refusal to join the 30% Club "inexplicable" and said Britain's acid rain policy displayed a "regrettable lack of good neighbourliness".

The political debate

A British chemist, Robert Angus Smith, was the first person to identify the link between industrial emissions and acid rain, nearly a century before interest was revived in Europe. The 1863 Alkali Act, which was introduced to control hydrochloric acid gas pollution from the British alkali industry, was the first air pollution law in the world. London's Battersea power station, opened in 1929, was the first installation in the world fitted with an operational FGD system, which cleaned as much as 80-90% of the sulphur from the plant's emissions. London was one of the first cities in the world to respond to the effects of smog and to impose a successful smog control programme.

All the more irony, then, in the fact that Britain has been one of the last countries to acknowledge the need to take action to control the emissions that cause acid pollution, a position which has attracted growing criticism from Europe. Why then has Britain not bowed to international pressure? There are a number of reasons.

Firstly, the pressure has so far taken the form largely of public criticism and polite diplomatic negotiation, and has come as much from non-governmental groups as from governments. There have been protests from European governments — such as the February 1984 Nordic environment ministers joint statement encouraging Britain to rethink its position and agree to join the 30% Club — but there has been little direct pressure exerted on the British government.

Secondly, although many Britons are aware in general terms of the acid pollution problem, it is not yet a major public issue. Although there is now considerable — albeit patchy — evidence of acid damage in Britain, it is not yet as visible as it has become in some European countries. Widespread *visible* evidence provoked the early interest of Norway and Sweden in the issue, and helped convert West Germany. Neither has acid pollution yet become a major British media issue, although this position is slowly changing.

Thirdly, the principal threats to the British environment are considered to come from other sources, notably agricultural intensification. The efforts of many British environmental organisations are directed largely towards countryside conservation.

Fourthly, much rests with the attitude of the National Coal Board and the Central Electricity Generating Board. Until the CEGB can be convinced of the national economic benefits of reducing emissions there is little likelihood of any substantive reductions in British emissions. Ironically, the country that stands to benefit most from a reduction in British emissions is Britain itself, which generates nearly 90% of its own deposition.

Finally, the British government argues that it would be wrong to commit itself to a 30% reduction in SO_2 emissions by 1993 unless it was absolutely certain that it could meet that target. It claims to have already reduced SO_2 emissions by 25% in the last five years, but is unwilling to commit itself to an additional 5% over the next eight years.

Yet despite the hesitancy and inconsistency of its public statements, the government is not taking criticism of its acid pollution policy lightly. Apparently concerned at Britain's isolation following the West German turnabout in 1982, Giles Shaw, the then parliamentary undersecretary in the Department of the Environment, ordered a review of acid rain policy in order to find out what could be done — and how much it would cost — to cut SO_2 emissions over 10 years. [65] Department of the

Environment scientists concluded that significant reductions could best be achieved by fitting FGD equipment in several existing large power stations. The CEGB apparently opposed the plan, and no support was received from other government departments, with the result that the Treasury was able to veto the plan.

In May 1984 Prime Minister Margaret Thatcher called a briefing session on government acid pollution policy, involving senior scientists and ministers. She had probably been partly motivated by her campaign to win allies in the European Community in support of Britain's attempts to reduce its budget contributions to the Community. According to the authoritative British environmental monthly *ENDS Report*, environment minister William Waldegrave and Dr Martin Holdgate (chief scientist at the Department of the Environment), argued that Britain should signal willingness to join the 30% Club and take a positive line on NO_x reduction. But objections from the Treasury, Lord Marshall and Energy Minister Peter Walker persuaded Mrs Thatcher to defer any specific commitments.

At the 1984 Multilateral Conference on the Environment in Munich, William Waldegrave argued that while Britain had "difficulty" with an immediate commitment to join the 30% Club, it was prepared to promise making "further substantial" SO_2 reductions (in addition to the 20% reduction since 1980) in a "reasonable timescale", and "parallel" cuts in NO_x. Martin Holdgate told the conference that Britain wished to see the environmental deterioration caused by air pollution halted and, where possible, reversed, but that government concern was "to base action on a proper understanding of the factors that change and damage the environment".

Mrs Thatcher has not only faced criticism from two all-party parliamentary committees. The Bow Group, supported by 95 centre-left Conservative members of parliament, argued in mid-1984 that the Conservative party would "reap electoral credit" if the government was to agree to cut SO_2 and NO_x emissions, and that Britain should join the 30% Club. [66] In December 1984 Conservative members of the European Parliament decided not only to join but to put themselves at the head of the majority group of MEPs critical of the British Government position. They believed that they had the tacit support of Environment Secretary Patrick Jenkin, of Foreign Secretary Sir Geoffrey Howe, and of William Waldegrave, and that their open opposition could encourage the Council of Ministers to override a British veto of the EC directive on large plant emissions.

As this book goes to press, the evidence continues to mount on the links between pollutive emissions and acid deposition in Britain, and criticism of the government position from scientists, pressure groups, Scandinavia, the European Community and the British Parliament itself continues to grow. The British government moves closer to the day when it must align itself with international agreements. It is no longer a question of 'if', but of 'when'.

Chapter 8

The European Community and the rest of Europe

In 1980, the 10 European Community member states (Denmark, Belgium, France, Greece, Ireland, Italy, Luxembourg, the Netherlands, West Germany and the United Kingdom) produced 17.6 million tonnes of SO_2 emissions. Every member state both emits and receives acid pollution, but the Netherlands, Denmark and Belgium are net importers, with 71%, 54%, and 53% of their sulphur respectively coming from outside their borders. Britain, by comparison, derives only 11-12% of its sulphur from other countries.

Forest damage is the critical factor in European Community (EC) acid pollution, which has in turn made vehicle emission controls a hotly debated political issue. Community forests cover 35 million hectares (86 million acres), or a fifth of the total land area, and employ 1.4 million people, about as many as are employed by the European motor industry. Forest damage thought to be linked to acid pollution has now been confirmed in all EC states but Greece, Ireland and Italy.

At a June 1983 meeting of the Heads of State and Government of the European Community in Stuttgart, a call was made for "immediate action" by the EC to avoid an "irreversible situation", and for EC measures aimed at "rapid significant progress" towards acid pollution control. As of late 1983, EC action consisted of four groups of directives (regulations that are binding as regards the result to be achieved, but leave form and methods up to member states) on the sulphur content of gas oil (light fuel oil) (adopted 1975), on lead in petrol (1978), and on air quality standards for SO_2 and suspended particulates (1980) and for lead (1982), and a group of directives on vehicle exhaust emissions introduced since 1974. The directive on SO_2 and suspended particles, which established an ambient (background or surrounding) standard of 120 micrograms of SO_2 per cubic metre, was initially opposed by the UK (which objected to a Community-wide air quality standard), Ireland (which felt it would hamper its plans for industrial expansion) and West Germany (which felt the techniques for measurement were too imprecise). But the accession of all the EC member states to the UN Economic Commission for Europe (ECE) transboundary pollution convention made the dissentors less inclined to oppose the SO_2 directive, and it was adopted in 1980.

	SO_2 emissions ('000 tonnes)	*Sulphur deposition (%)*		
		Foreign	*Domestic*	*Undecided*
UK	4,680	12	79	9
Italy	3,800	22	70	8
France	3,270	34	52	14
West Germany	3,200	45	48	7
Belgium	809	53	41	6
Greece	700 (est.)	51	37	12
Netherlands	480	71	23	6
Denmark	437	54	36	10
Ireland	170	32	28	40
Luxembourg	50	73	27	0
TOTAL	17,596	—	—	—

[Note: The Western European countries receiving the greatest proportion of total deposition from foreign sources are (in order): Switzerland (78%), Austria (76%), Luxembourg (73%), the Netherlands (71%), Norway (63%) and Sweden (58%). Those receiving least from foreign sources are the UK (12%), Spain (18%), Italy (22%), Ireland (32%), Portugal (33%) and France (34%)].

Figure 10. SO_2 emissions and sulphur deposition in the EEC. Source: EMEP 1980.

The ECE, which works collectively on joint Community policy rather than in individual national interests, develops directives and submits them to the EC Council of Ministers, which must give unanimous approval before a directive becomes Community law.

Since the beginning of 1984 there has been a relative flood of proposals from the Commission, suggesting — among other things — regulations and directives on combatting air pollution from industrial plants, establishing a scheme to provide EC forests with increased protection against acid rain, limiting emissions from large combustion plants, and setting air quality standards for NO_x. The Commission responded to the Stuttgart meeting with a five-point plan building on existing directives and proposing new measures. The plan included a revival of a 1976 proposal for a directive on sulphur emissions from the burning of fuel oil and a comprehensive package of measures to control vehicle emissions.

Vehicle emission controls are proving a controversial issue. The EC has proposed a two-stage conversion to unleaded fuel: by 1989 for new models and by 1991 for all new vehicles, followed in 1995 by the application of

US emission standards. But in 1983, West Germany pre-empted everyone by announcing that unleaded petrol and catalytic converters for all new motor vehicles would be mandatory from 1 January 1986. The EC charged that the West German move was illegal under existing directives, which bar member states from banning imports of any vehicles that meet EC standards. West German car manufacturers protested that banning imports of vehicles without converters would draw retaliation from other countries, and British car manufacturers argued that catalytic converters would increase petrol consumption by 10%. France, Italy and Britain argued that the West German move would break up the Community road vehicle market and lead to a flood of Japanese cars already fitted with emission controls. France formally complained to the European Commission that West German plans amounted to a barrier to trade under the Treaty of Rome. West Germany for its part quotes Article 36 of the Treaty of Rome, which allows the imposition of trade restrictions on grounds that include "the protection of health and life of humans, animals or plants".

In January 1984 there were signs that the West Germans were beginning to doubt that they could meet their own deadline. In September 1984 West Germany replaced the 1986 target with a decision that all cars sold there from 1 January 1989 would have to be fitted with catalytic converters, although voluntary controls would still be encouraged from July 1986, including providing motorists with incentives like cuts in car tax.

This still anticipates by six years the timetable proposed by the EC. In December 1984 the Council of the EC adopted two directives: one agreeing that unleaded petrol must be on sale in all member states by 1 October 1989 (in effect, this means petrol must not have more than 0.13g/l of lead, in line with the US limit), and one setting limits on nitrogen dioxide in the air (agreed in March 1985). The European Commission has asked member states to try to agree Community-wide emission standards by the end of 1986.

As this book went to press, the Commission had just proposed emission standards aimed at halving car exhaust emissions. EC member states agreed in principle in March 1985 to establish standards on emissions from petrol-driven cars of carbon monoxide, hydrocarbons with NO_x, and NO_x alone. The standards take into account European driving patterns, and there are different standards for large cars (more than two litres), medium cars (1.4-2.0 litres) and small cars (under 1.4 litres), and different timetables for the introduction of controls. By October 1994 every new car sold in the EEC will have to comply; larger cars will have to fit catalytic converters, and smaller cars will use lean-burn engines.

A resolution of the NO_x problem would further emphasise the need to control SO_2 emissions. A number of European countries see the prospects for ECE action on SO_2 being hindered by East European member nations, and put greater faith in the possibilities of EC action.

A 1983 study of national acid pollution policies by two US lawyers, Gregory Wetstone and Armin Rosencranz, concluded that, despite its limitations, the Community was "the organisation most likely to eventually succeed in establishing international SO_2 control programmes in response to Europe's transboundary pollution problem". [67]

Belgium: acid damage barely investigated

Belgium reduced its sulphur emissions by more than 40% between 1973 and 1982 [68], and has joined the 30% Club. More than half its sulphur deposition came from other countries, mainly France, Britain and West Germany. Existing Belgian air pollution control legislation, dating back to 1964, consists mainly of measures aimed at traffic and domestic heating (which account for 16% of emissions), while setting no emission limits for industry and power stations. A task force has been set up to look into the implementation of Belgium's undertaking to reduce emissions by 30% by 1993. In 1983, regulations on SO_2 and suspended particulates were introduced in line with the 1980 EEC directive, but as the levels had already been met throughout much of Belgium, this amounted to little more than legitimisation of the status quo. [69]

Belgian utilities argue that retrofitting power stations with flue gas desulphurisation (FGD) systems would be too expensive, and there are fears that they may be using the acid pollution issue as an excuse to expand the Belgian nuclear power programme. Electricity companies argue that the shift from oil and coal to nuclear power cut SO_2 emissions by 25% between 1980 and 1982, and that an overall reduction of 60% could be achieved by 1986.

Acid damage in Belgium has barely been investigated. According to selective studies, rain over northeastern Belgium has had pH values as low as 3.8 to 4. In Antwerp, the mean value is pH 4. Belgian soils are generally rich in buffering agents, but some regions are not. Some moorland pools in the Campine Fens, although naturally slightly acid, now have pH values as low as 3.8. Fish have disappeared from the fens, and in Wallonia trees show signs of damage, but in neither case has a link yet been made with acid pollution. Along the border with West Germany, 70% of forest cover is reported to be damaged. The environmental party Ecolo won 16% of the vote in the 1984 European Parliament elections in the region, well above the national average.

Denmark: emission reduction plans

Denmark exports nearly two-thirds of its sulphur emissions, mainly to

Sweden and Norway. It has joined the 30% Club and, to meet its commitments, plans to reduce the sulphur content of heavy fuel oils from 2.5% to 1.5%, and of light fuel oils from 0.5% to 0.3%. This should reduce emissions from local heating plants, domestic heating units and diesel-powered vehicles, which together account for about half Denmark's sulphur emissions. The remaining half come from power stations; government proposals to control these emissions rely partly on FGD. A government Commission on Acidification estimates that the total cost of achieving a 30% emission reduction will be about DKr 3-4 billion ($180-240 million) over nine years, and will add less than 0.001 of a cent to the price of a kilowatt-hour of electricity by 1995. [70]

A Danish College of Technology survey on the western peninsula of Jylland found about 1,000 hectares (2,500 acres) of damaged forest, of which about 10% was dead. Soil samples revealed high concentrations of aluminium and almost no calcium.

France: another turnaround

Links between tree death and industrial pollution have long been known in France. As early as 1953, trees were dying near the Houilleres power station in Lorraine. Research in 1978 found that only conifers were being affected. The oldest needles were dying first; the trees were being weakened and then dying from the effects of insects boring through the bark. Oaks near petrochemical centres in the Seine estuary have also died.

France has 13.6 million hectares (33.6 million acres) of forest, covering nearly a quarter of the land area and constituting about a third of all the forest in the EC. Two-thirds of the trees are deciduous and a third evergreen. France has comparatively lime-rich soils, few lakes and moderate amounts of air pollution fallout from other countries.

The most serious effects of acid pollution seem to be those of dry deposition on forests. Among the most seriously affected French forests are those in the Vosges highlands in northeast France. Following reports of damage in 1983, the French environment ministry launched a monitoring programme in the Vosges, and 200 observation posts were established to assess rain, air and water quality and tree growth. National Forestry Office figures published in June 1984 revealed that 35,000 hectares (86,000 acres) were affected, of which 5,000 hectares (12,000 acres) were seriously affected. In October 1984 the environment ministry admitted that 10% of the Vosges forest was affected. By early 1985 one in every five conifers in Vosges was reported to be dying.

Forests throughout Alsace are also affected. In the Donon massif, firs have been losing their needles for four years. The worst affected trees are those on higher ground and those exposed to southerly and southwesterly winds. Trees of all ages are damaged, including young saplings. Pine tops have been thinning, and since the autumn of 1983 even established trees of 3-4 metres (10-13 feet) have been attacked by insects for the first time. Leaves on beeches have been found to be thinning and yellowing. Studies in the southern Vosges have found that trees die off faster after several days of good weather, suggesting a link with ozone formation.

Other areas affected include Jura, the Alps, the Massif Central and the Pyrenees. One German scientist has claimed that there is clear evidence of forest damage in an "almost unbroken profile from Bretagne in the west to the Vosges in the east, and also in central France, towards the middle and east" [71], but so far this has not been supported by the French.

Until 1984, France concurred with West Germany and the UK in rejecting the need to reduce pollutive emissions. Then, like West Germany, it switched sides, (with nuclear power replacing coal, there is little economic sacrifice involved in reducing French emissions) and joined the 30% Club. It has gone so far as to commit itself to a 50% reduction in SO_2 emissions by 1990, regardless of changes in its economic position. This, announced the Ministry for the Environment and Quality of Life, would be achieved by the use of "clean energy" and the "diversification of energy sources". This in effect means further investment in nuclear power. France has one of the most active nuclear power programmes in Europe, and plans by 1990 to meet 27% of its energy needs with nuclear power (compared to 7% in 1980). Other measures include energy conservation and the treatment of flue gases.

Greece: major smog problems

Its geographical separation from its EC partners means that Greece contributes little to Community acid pollution. Nearly two-thirds of its annual SO_2 emissions of 700,000 tonnes are redeposited within Greece. As a relatively lightly industrialised country, its most immediate problems come from smog, for which Athens in particular is notorious. At the 1982 Stockholm conference, the Greek Minister of Physical Planning, Housing and the Environment, A. Tritsis, observed that a priority area for action was Attica, the region of Athens where strict emission controls had been imposed, including the exclusion of cars from the centre of Athens and the relocation away from Athens of heavy-polluting industries.

SO_2 is less of a problem in Athens than NO_x from road traffic. Attempts have been made to reduce the number of cars in the city from the present figure of 500,000. In January 1984, air pollution became so bad that the government ordered a 30% cut in industrial production, reduced central heating in public buildings, and banned some vehicles from the city. As the smog persisted, a 9,000 hectare (20,000 acre) zone was declared in which cars and taxis were allowed to travel only on alternate days [72].

In July 1984, a heat wave caused levels of smog in the city to rise so alarmingly that the government had to impose emergency measures to protect the health of Athenians and maintain its own political credibility. Half the private cars on the streets were ordered off for 48 hours and industries were told to cut fuel consumption by 30%. About 500 people were hospitalised with respiratory complaints in the space of two days. [73]

The Acropolis Committee — consisting of architects, chemists and archeologists — was formed in 1975 with the aim of restoring the Acropolis (damaged largely by air pollution) by 1991 at an estimated cost of $65 million.

Greece did not sign the LRTAP convention protocol on SO_2 in July 1985, citing "technological problems" relating to its heavy dependence on lignite. National development plans involve a rapid and substantial increase in energy generation, but — said the Greek delegation at Helsinki — Greek sulphur emissions nevertheless remained "insignificant" by comparison to other countries.

Ireland: little industry, little acid

As the westernmost landmass in Europe, as one of Europe's least industrialised countries, and with annual SO_2 emissions (170,000 tonnes) and deposition (150,000 tonnes) among the lowest in Europe, Ireland barely has an acid pollution problem. The acidity of Irish rain appears to be increasing only slightly: a July 1984 report by the government environmental agency An Foras Forbortha noted that acidity in rainfall had increased steadily over four five-year periods from pH 5.9 to 5.5. A team from Trinity College, Dublin revealed in December 1984 that samples taken at Glencree, Co. Wicklow, over a period of 10 months had revealed three acid rain episodes strong enough to cause nutrient leaching from soils.

However, the construction of a new coal-fired power station at Moneypoint (near Ennis, Co. Clare), threatens to increase the risk of acid pollution. Burning coal with a sulphur content of 1.6%, Moneypoint's two tall stacks will disperse 65,000 tonnes of SO_2 to the winds, more than doubling the present SO_2 output of the Irish Electricity Board (ESB) and increasing total Irish emissions by more than a third. The ESB defends its decision not to include emission controls on the grounds of insufficient data and questionable efficacy of controls, and argues that emission controls would increase electricity rates by 20%. [74] The Irish government admits that once it runs out of the sulphur-free natural gas that currently generates 50% of Irish electricity, the need to use different fuels will lead to an unavoidable rise in SO_2 emissions. For the time being though, Ireland only generates 1% of total EC SO_2 emissions, and argues that committing itself to a 30% reduction would have no measurable benefit for the European environment, but would have adverse consequences for the Irish economy.

Italy: major emissions, but little research

Italy emits 3.8 million tonnes of SO_2 per year, making it second only to the UK in Western European emissions. Although 70% of its emissions are redeposited within its borders, air pollution is not yet a major issue, and few studies have been made into possible environmental damage. Lake acidification has been reported, as has some forest damage. Northern Italy, including the Po Valley, is at particular risk because of the proximity of industrial centres such as Milan, Turin, Genoa and Venice. Dry deposition is thought to be the critical factor in the Po Valley and wet deposition in Alpine regions. The combined effects of dry deposited air pollutants and a damp sea climate are visible in Venice, where monuments, buildings and works of art are being eaten away by corrosive air and water, and an international effort has been launched to save the cultural treasures of the city.

Luxembourg: tiny but polluted

Luxembourg is the smallest (2,590 sq km/1,000 sq miles) member state of the EC, but receives proportionately as much sulphur deposition as its neighbours; in fact it receives more sulphur from outside its borders (73%) than any European country except Switzerland and Austria. In August 1984 a nationwide survey of Luxembourg's forests revealed that just under a fifth of the total area was damaged, and about 4% was badly damaged. Worst affected were stands of mature trees, of which almost 30% were damaged. Continuous observations made of 15 selected stands of spruce on particularly exposed sites from September 1983 to September 1984 revealed that the proportion of damaged trees increased from about 5% to more than half. [75]

The Netherlands: major forest losses predicted

The Netherlands is the fourth biggest importer of sulphur (71%) in Europe. Although Dutch SO_2 emissions fell from 900,000 tonnes in 1965 to 480,000 tonnes in 1980, lakes and forests have been damaged. A 1982 survey of 70 lakes in the southeastern Netherlands found that 56 were acidified. Extensive inventories in the second half of 1983 revealed that the cost of acidification in terms of reduced harvests and corrective action — additional liming, more intensive maintenance and conservation of areas of natural beauty, restoration work and measures to protect items of cultural and historical interest and consumer goods, and measures in the forestry sector — was 150-500 million guilders ($28-95 million) per annum. Without corrective action, annual costs could rise to 300-1,000 million guilders ($57-$190 million) in capital losses, the costs of rehabilitating forests, reduced timber yields and contamination of drinking and industrial water supplies. Capital losses in forestry could be of the order of 10 billion guilders ($1.9 billion).

A survey by the Dutch Forestry Service (December 1984) catalogued the extent of forest damage in 2,800 sites over a total land area of 281,000 hectares (695,000 acres), amounting to 85% of all Dutch woodlands. Just over half the trees were considered healthy; about 40% showed signs of damage but were expected to recover; about 8% were seriously damaged (only partial recovery likely), and 1.5% were irreparably damaged. Coniferous species — particularly the Scots pine — were the most seriously damaged. Five possible contributory factors were examined, including insect and fungal attack, climate and soil variations, tree age, the physical form of woodlands and the mix of species. The major conclusion was that there was a clear link between tree damage and the vulnerability of the soil to acidification. Trees growing on thin sandy soils were less healthy than those on clay soils.

The Netherlands is a member of the 30% Club, and has undertaken in addition to cut annual SO_2 emissions by 70%, and NO_x emissions from motor vehicles by 30%. This will be achieved by making 90% FGD compulsory for all coal-fired power stations by 1990; the Netherlands will also fit catalytic converters to motor vehicles in line with the EC timetable. Unleaded petrol is due to be introduced in October 1986.

Austria: curbing vehicle emissions

Forest covers more than 45% of Austria, and accounts for about 10% of export revenues. About 16% (600,000 hectares/1.48 million acres) is already reported damaged. If nothing is done to reverse the trend, Austria stands to lose 4.2 million cubic metres (148 million cubic feet) of timber annually, worth an estimated $166 million.

Austria exports 60% of its annual SO_2 emissions of 440,000 tonnes, while 76% of the SO_2 deposited in Austria is of foreign origin. Austria has taken measures to reduce its emissions, and is also active in international pressure to introduce vehicle exhaust emission controls.

	SO_2 emissions ('000 tonnes)	Sulphur deposition (%)		
		Foreign	*Domestic*	*Undecided*
Spain	2,730 (1985)	18	63	19
Turkey	1,000	39	42	19
Austria	440	76	15	9
Portugal	170	33	27	40
Switzerland	119	78	10	12
Iceland	10	25	0	75

Figure 11. SO_2 emissions and sulphur deposition in Europe outside the Community. Source: EMEP/UNECE 1980-81.

About 70% of Austrian NO_x emissions are thought to be caused by road traffic. In August 1983 it became the second European country after West Germany to announce that it would introduce unleaded petrol. From 1 October 1985 unleaded petrol was available at all petrol stations. Austria's announcement of a switch to unleaded petrol came after a meeting between the Austrian and West German health ministers, and reflected a concern equal to that of West Germany about the effects of acid on forests. Austria was one of the founding signatories of the 30% Club, and in Helsinki in July 1985, announced that it was prepared to reduce its sulphur emissions by 50% by 1993 (on 1980 levels).

Spain: more research needed

With estimated annual SO_2 emissions in 1985 of 2.73 million tonnes, Spain is the fifth biggest source of SO_2 in western Europe. According to EMEP, nearly two-thirds of its deposition is self-inflicted, and only 18% comes from foreign sources, although Spain's Instituto Nacional de Meteorología (INM) argues that because there has been virtually no research, there is too little data on air pollutants to be sure.

Initial studies, mainly those undertaken by Ing Mariano Seoanez Calvo, suggested that 300,000 hectares (740,000 acres) were already affected by acid deposition. The areas worst affected by acid pollution were the Cornisa Cantábrica on the north coast, downwind of the major industrial areas of Bilbao and Avilés, and the areas around the power stations of Serchs (Barcelona), Andorra (Teruel) and El Serrallo (Castellón). There were reports from the Bilbao area as early as 1970 of housewives finding small holes in clothes hung out to dry. A 1982 report [76] estimated that industry in Avilés alone generated 24,000 tonnes of SO_2 annually. High levels of atmospheric sulphur pollution have been recorded in San Juan de Nieva: the biggest single source of SO_2 in the region is the Ensidesa steelworks.

A technical commission set up to study pollution in the forests of El Maestrazgo and Els Ports de Tortosa-Beseit, which spread over three provinces, suggested that emissions from the Andorra might be affecting these forests. [77]

Spain ratified the ECE convention in June 1982; it feels that transboundary and acid pollution is less of a problem in Spain than in other countries, but admitted in its statement to the July 1985 EB meeting in Helsinki that its accession to the European Community in January 1986 may involve "a difficult and costly adaptation" of its environmental policies.

Switzerland: biggest foreign deposits

Swiss SO_2 emissions (119,000 tonnes) are among the lowest in Europe, but Switzerland imports more sulphur (78%) from outside its borders than any country in Europe. This has serious implications for its forests, which cover more than a quarter of its land area. In 1983 a quarter of the firs and 10% of the spruces in flatland cantons (Aargau, Solothurn, Thurgau) died, and 8-14% of Swiss forests were thought to be damaged. Early in 1984 the Swiss government allocated 30 million SFr ($13 million) for measures to combat forest damage and forest death. Since then 12 million sick trees have been felled (or 14% of the total of Swiss forests). [78]

According to a systematic survey of 27,000 trees in mid-1984 by the Swiss Forestry Research Institute, a third of Swiss trees were damaged, and 8% seriously damaged or dying. Only on 2% of the trees could the damage be directly attributed to insects, fungi or snow falls. The worst damage was in the southern Alpine cantons of Grisons and Valais, where 50-60% of the trees were affected. [79]

About 75-80% of the pollutants deposited in Switzerland come from other countries. Switzerland is a 30% Club member, and now has the strictest vehicle exhaust control regulations in Europe. On 1 January 1985 Switzerland introduced two new regulations to control NO_x emissions. Firstly, only unleaded petrol can now be imported or delivered by Swiss refineries; from 1 July 1986 only regular unleaded petrol will be sold. Secondly, speed limits on motorways were reduced from 130 kph to 120 kph (80 to 75 mph), on ordinary open highways from 100 kph to 80 kph (62 to 50 mph), and in built up areas from 60 kph to 50 kph (37 to 31 mph). Other measures being considered include more efficient control of vehicle exhausts, more efficient control of home heating installations, and reductions of the sulphur content of light heating oil.

Turkey: little yet known

Acid pollution has not yet been firmly identified in Turkey, but substantial SO_2 and NO_x emissions provide major potential; the most recent estimate of Turkish SO_2 emissions (EMEP 1980) was one million tonnes. About 42% of its sulphur deposition is self-generated. In 1981 it was estimated that nearly 94% of industrial plants were sources of pollution. Istanbul, with more than 43% of the country's industry, faces some of the worst problems. Sources of SO_2 include fertiliser plants, the iron and steel industry, steam plants in the sugar industry, textile factories, petrochemical plants and thermal power plants.

In the town of Murgul, near the Soviet border, copper has been mined since 1907, and an old blast furnace gives off SO_2 emissions that have killed plants, fruit trees and forest over a 10 km (6 mile) stretch of land. Annual crop yields in the area have fallen by 80%. Around Izmir, on Turkey's west coast, crops such as tobacco, cotton, grapes and tomatoes have been damaged by residential and industrial emissions. Ankara's position in a valley makes the capital susceptible to overnight fogs, and industrial emissions have been implicated in the persistence of fogs after sunrise and the formation of dry summer fogs. Readings from 13 monitoring stations in the late 1960s confirmed high levels of SO_2, NO_x and hydrocarbons in the city's air, thanks largely to Ankara's strong dependence on lignite, which provides more than a third of its energy needs. The eastern Turkish city of Erzurum has even higher concentrations of SO_2 than Ankara.

Chapter 9

The USSR and Eastern Europe

Marxist philosophers often describe environmental problems as capitalist problems. Engels wrote in 1876 that capitalists engage in production and exchange for the sake of profit, and do not concern themselves with the environmental effects. [80] Economic development under socialism is portrayed as more positive and more public-spirited. Article 18 of the Soviet Constitution states that in the interests of present and future generations, the necessary steps should be taken "to protect and make scientific, rational use of the land and its mineral and water resources" and "to preserve the purity of air and water ...and improve the human environment".

But recent evidence — both official (published by government departments and officially sanctioned scientific research groups) and unofficial (usually smuggled to the West by dissident groups) — seems to suggest that environmental degradation in the European Soviet Union and Eastern Europe is common, and, in many places, critically serious. Air pollution is known to be severe in the industrial centres of Poland and Czechoslovakia, and there is mounting evidence of damage in East Germany and the Soviet Union. Professor Ingmar Oldberg of Sweden's University of Lund observes: "Factory managers in the communist countries are even worse polluters than their equivalents in the West. They will dump anything into a river if it will help them fulfil the plan and earn them a bonus." [81]

The environmental effects of Eastern European industrialisation are compounded by the concentration of heavy industry in a relatively compact and crowded landmass, the widespread reliance on high-sulphur coal, and prevailing winds which blow the pollution across complex river systems and heavily forested regions and from Eastern Europe into the Soviet Union.

The Soviet Union (USSR): the world's biggest producer of SO_2

Data on environmental deterioration of any kind in the USSR is variable, and Western assessments of Soviet acid pollution must rely largely on balancing official and unofficial reports. The Soviet delegation to the 1984

	SO_2 emissions ('000 tonnes)	Sulphur deposition (%) Foreign	Domestic	Undecided
USSR	25,000	32	53	15
East Germany	4,000	32	65	3
Czechoslovakia	3,100	56	37	7
Yugoslavia	3,000	41	51	8
Poland	2,755	52	42	6
Hungary	1,633	54	42	4
Bulgaria	1,000	47	45	8
Romania	200	56	36	8
Albania	c 100	67	15	18

Figure 12. SO_2 emissions and sulphur deposition in Eastern Europe. Source: UNECE/EMEP 1980-81.

Munich Conference admitted that there was acid damage in the Soviet Union, the pollution originating both from internal and external sources; there is particular concern about pollution from neighbouring Eastern European states. Poland, Czechoslovakia, East Germany and Hungary, equipped as they are with old-fashioned, heavy and dirty industrial and power plants, export large quantities of pollution to the USSR, which is now a net importer of SO_2.

The critical region is European Russia (west of the Urals), which constitutes less than a quarter of the area of the USSR, but supports more than three-quarters of the population, and most of the industry, agriculture and forestry. At 22.4 million sq km (8.65 million sq miles) the USSR covers one-sixth of the earth's total land area.

Emissions. The USSR is the world's biggest source of sulphur dioxide emissions — about 25,500 million tonnes per year. Thermal power plants generate 60% of Soviet electricity, and are the source of 50% of Soviet SO_2 emissions and 40% of NO_x emissions. Internal emissions are seen as less of an issue by the Soviets than the so-called transboundary fluxes affecting neighbouring countries. The Soviet Union argues that only 3-4% of the air pollutants produced within the USSR ever cross Soviet borders, and so is unwilling to commit itself to any total reductions by a fixed percentage, but claims that it need only reduce its transboundary fluxes by, say, 30% in order to fulfil international demands and show consideration for the environment of other countries.

Southwesterly winds bring large amounts of air pollutants from other countries — mainly from Eastern Europe — so that the USSR receives an estimated five to 10 times more pollutants than it exports over its western borders. According to EMEP, in the period 1979-81, more than five million

	1980	*Est. for 1990*
Solid fuels (hard coal)	27%	26%
Liquid fuels (oil)	36%	30%
Natural gas	27%	32%
Hydroelectric	3%	3%
Nuclear power	1%	6%
Other sources	6%	3%

Figure 13. Soviet energy structure.

tonnes of sulphur compounds per year were carried into the USSR across its western borders, resulting in "grave damage" to the Soviet environment. About 900,000 sq km (350,000 sq miles) of European USSR is now thought to be affected by acid precipitation, particularly along the western border. This is only 4% of the total area of the USSR, but over 16% of the area of European USSR.

Electrification has been a central energy goal in the USSR since the revolution. The Soviet Union has considerable energy resources within its own borders, including the biggest coal reserves in the world (mined in the Ukraine, western Siberia, and Kazakhstan), major oil fields in the Caspian Sea and Black Sea, and natural gas fields in the Caspian and in the Urals. Both oil and natural gas is taken in huge pipelines from the Soviet Union (mainly from the Volga and Caspian fields) to Eastern Europe and to the major industrial centres of the USSR.

Acid damage. Damage has been reported to forests, lakes, soils and crops, but details are limited. According to the Soviet report to the Munich conference, two marked trends have been identified in forests in the European USSR: the reduced ability of conifers to renew their growth and a die-off in oaks.

In Byelorussia between 1956 and 1978, the proportion of oak in forests fell from 4.8% to 3.9%, despite the cultivation of 50,000 hectares (125,000 acres) of new oaks. The Soviet newspaper *Pravda* reported recently [82] that vast areas of forest were dying from air pollution near the automobile-manufacturing city of Togliatti, about 1,300 km (800 miles) east of Moscow. The report observed that forests along the Volga River could soon turn to wasteland. According to unofficial reports [82a], forest damage could soon reach the point where 300,000 hectares (750,000 acres) of Soviet forest land is affected by acid deposition.

Lakes in the European USSR are apparently as susceptible to acidification as lakes in Scandinavia. This applies especially to lakes in the northwestern USSR, particularly in the Kola Peninsula and in Karelia, which are geologically similar to Scandinavia. But no survey of vulnerable lakes has been reported, although low pH-values in precipitation have been registered.

Soviet acid pollution has particularly serious implications for agriculture. There is an uneven struggle between production and demand, and for years a major policy goal has been increased grain yields to support increased production of meat and other livestock products. Western estimates put the 1984 Russian grain harvest at about 170 million tonnes — 70 million tonnes below target. Shortages have compelled the Soviet Union to import grain from other countries, including the United States.

Drought, poor organisation, poor transport and distribution systems, waste, inefficiency, bad discipline, and inadequate maintenance of machines and other equipment all contribute to the failure to meet agricultural goals. But the USSR now seems to be facing the prospect of additional shortages caused by acid damage. Acid pollution is believed to be implicated in the annual loss of between 80 and 120 million roubles ($65-100 million) worth of agricultural yields, although sources quoted by UNEP put the figure much higher. According to the Soviet report to the Munich conference, some 15% of the harvest in an area of 40 million hectares (100 million acres) is lost, representing yields worth $580 million.

Measures have been taken to counteract the effects of acid deposition. In the European USSR, 1.5 million tonnes of lime have been spread per year to neutralise an equal amount of deposited sulphur, but the damage continues. Naturally acid soils are common in the northwestern and central European USSR. In 1982 a Russian scientist at the Stockholm conference concluded that additional acidity in these soils could cause deterioration of their nutrient capacity and reduction of their productivity. Such adverse effects could also threaten the forests in these regions.

Controlling emissions. In 1981, the book *The Destruction of Nature in the Soviet Union* was published in the United States. Written by 'Boris Komarov' (said to be the pseudonym for a senior Soviet official), it argued that ecological damage in the Soviet Union was primarily a result of the self-interested actions of a bureaucratic élite which knew the scale of the Soviet ecological crisis, but had neither the desire nor the means to resolve it because to do so would threaten their privileges. 'Komarov' notes that the USSR has the strongest emission standards in the world for many pollutants, but they have generally remained "an abstraction, an ideal for which industry should strive". Dust and particle filters have been fitted in many factory chimneys, he notes, which gives the visual appearance of clean air; but SO_2 and other gas emissions remain.

Officially, the Soviet Union plans to reduce its emissions largely by using more nuclear power, although thermal power will continue to play a major role in the Soviet fuel-energy balance. Under the State Energy Programme, which will take energy planning well into the 1990s, the Soviet Union also plans a growing substitution of oil by natural gas, increased use of secondary energy resources (such as waste heat from industry), accelerated development of coal-burning power plants using low-sulphur coals from the eastern USSR, the development of hydro-energy resources, and intensified use of peat and biomass.

A two million tonne cut in SO_2 emissions over 1980-84, was achieved by fuel desulphurisation, flue gas desulphurisation (FGD), the introduction of new low-waste and low-energy technologies, energy conservation, extensive use of low-sulphur coals and gas, accelerated development of nuclear power and further use of hydro resources. [84] These reductions were intended to have the biggest impact in European USSR.

Under the State Energy Programme, a further 10 million tonne reduction in SO_2 emissions is planned by the year 2000. This will be achieved by modernising power plants in European USSR, and further conservation, fuel processing, new combustion technology and FGD. The Soviet Union and the republics of the Ukraine and Byelorussia have undertaken to reduce their transboundary fluxes of SO_2 by 30% by 1993 or 1995. They plan to use low-sulphur coal and replace fossil fuel-fired power stations with nuclear power plants. Moscow has probably the world's largest district heating system. All its plants are now reportedly fuelled with natural gas.

There are plans to control NO_x emissions from industry and power plants by modifying combustion processes. Given the Soviet Union's extensive public transport systems, NO_x from motor vehicles is not a major issue. Trucks are the source of more than 70% of the exhaust gases from Soviet motor vehicles. Future measures are aimed at designing new types of engines, using more diesel engines, increasing the production of vehicles operating on compressed or liquified natural gas (to one million by 1990), gasohol or electricity. More new cars will also be fitted with catalytic converters. These measures will, according to the Soviets, reduce emissions from motor vehicles by 30% by 1993, while the number of vehicles on Soviet roads increases.

German Democratic Republic: not enough cash

East Germany claims that if it had the financial resources, it would be actively in favour of controls on atmospheric pollution. "Our experts are working on various methods to reduce the emissions", commented an East German diplomat at Munich. "But we are in no position to present a time schedule for the exact implementation of all measures. Even though there is indeed a will, the economic constraints are not easily overcome."

Data on established and anticipated damage from air pollution in East Germany is variable. Official sources are highly selective, and while visitors can see some of the damage for themselves, they rarely see the worst affected areas. But East Germany is the most heavily industrialised country in the Eastern bloc, and its SO_2 emission levels per unit area (about 35 tonnes per sq metre) are known to be the highest in the world. Damage to forests has been officially — if reluctantly — admitted, and some SO_2 and NO_x emission controls have already been implemented, with more planned. Yet East German officials and scientists tend to play down the implications of transboundary air pollution and acidification. Damage in industrial areas is referred to as "a local problem". While West Germans speak of 'saurer Regen' (acid rain), East Germans speak of 'rauchgeschädigte Flachen' (areas damaged by smoke). Soil acidification has also been identified, but is blamed mainly on unnatural climatic conditions. No surface water acidification is said to exist, either because the surface water is often naturally acid (as low as pH 4.9 in highland moors), or because excess acidity is buffered by the soil (in central and northern parts of the country).

Emissions. East Germany is the world's biggest producer of brown coal, producing more than a quarter of the world total. Hence brown coal accounts for the bulk of East German energy demand (70% in 1980, compared with 18% from oil, 9% from natural gas, and 3% from nuclear power). While the contribution of coal is expected to remain steady, and that of oil and gas to fall, nuclear power capacity is expected to more than double by 1990. About 12% of East Germany's electricity is already generated by nuclear power; one large plant is in operation and three are on order.

East Germany's annual SO_2 emissions are thought to be about four million tonnes, of which about 2.5 million tonnes are deposited within the country, and the rest exported to neighbouring countries, mainly Poland, Czechoslovakia, West Germany, the USSR and Sweden. No official figures have been released by East Germany since 1978, but it is thought that emission levels have remained constant since the early 1970s, while industrial production has grown by about 80%.

About 90-95% of the SO_2 emissions come from burning brown coal. In 1983 East Germany used 280 million tonnes of coal. With a water content of just over 50% and a carbon content of just under 25%, brown coal has a low thermal and energy value. Large quantities must be burned to generate the same amount of energy as lesser quantities of oil. Although the sulphur content of East German brown coal is about 1-2%, it contains elements that give it a degree of built-in alkalinity which helps neutralise some of the potential acidity. Its high water content means that brown coal cannot be burned at high temperatures, so the formation of nitrogen oxides is low — about 90% lower than with hard coal.

NO_x emissions from East German road vehicles are relatively low. Many vehicle engines are two-stroke, and produce, on average, only a tenth of the NO_x produced by four-stroke engines. Speed limits have been introduced: 100 kph (62 mph) on motorways, 80 kph (50 mph) on main roads, and 30-50 kph (20-30 mph) in urban areas. 'Transportation optimising' is regarded as the key to minimising NO_x emission from road vehicles; in other words, the encouragement of rail and water transport, public transport in the larger cities, and the use of more vehicles powered by natural gas.

Acid damage. The areas most affected by environmental damage correspond with East Germany's mining and industrial centres. East Germany has about three million hectares (7.5 million acres) of forest (covering 27% of the total land area). Of this, 75% is coniferous forest (spruce and pine), and 25% deciduous forest (mainly beech). Nearly two-thirds of all forests are owned by the state, 29% by agricultural cooperatives and the remaining 6% by the church and by individuals.

East Germany does not readily admit that forest damage exists, and no precise figures are given officially. However, damage has been reported to 350,000 hectares (865,000 acres), or 12% of the total forested area. [85] At the Munich conference, the East Germans reported damage in the Dübener Heide and Lausitzer Heide (heaths), in the central highlands, and in the southwest.

Soil acidification has been established in the Erzgebirge mountains (on the Czechoslovak border), and there have in the past been official admissions of forest damage in the industrial areas of Leipzig, Bitterfeld and Halle. Considerable damage is also believed to have occurred around Karl Marx Stadt (formerly Chemnitz), in the Cottbus area on the Polish border, in the Marienberg and Annaberg on the Czechoslovak border, and in the Fichtelgebirge on the West German border. Swedish experts visiting the area noted soil acidification in the south, southeast and southwest of the country.

East Germany officially holds that forest damage is due to the effect of toxic gaseous pollutants (mainly SO_2 and other airborne pollutants) and the synergistic effect of impaired breathing and nutrient uptake of trees. During extreme climatic situations, such as the droughts of 1975/76 and 1982/83, and the frost of 1978/79, the damage was worse.

The effects of air pollutants on forests are by no means unknown to East Germans. The Tharand Institute (a forest research institute founded in 1811) has, since the middle of the 19th century, carried out research on air pollutants and their influence on trees and other vegetation. Experiments are carried out today in an installation — unique in Eastern Europe — where pure or mixed gases are blown into mobile greenhouses containing conifers, crops or fruit trees. East Germany has built up a considerable store of knowledge about the effects of air pollution on vegetation, much of which has already been used to counter various types of damage.

Research has for example been carried out into adapting forests to present and continued high levels of air pollutants. Different conifers, particularly spruce, are being improved by breeding to produce varieties more resistant to pollution. Management methods for badly affected forest areas are being designed, and research carried out into the effects of mineral fertilisers, to establish whether they can strengthen and revitalise trees. Species of trees best adapted to different sites are selected; complete stands, or trees in the outer part of stands, are used as protective screens. Interim protective measures include intensive fertilising (23,000 hectares/57,000 acres per year), the 'spread of risk' (mixed plantations of conifers and deciduous trees: if one species is knocked out the other will provide a harvest), and the breeding of species tolerant to polluted air.

Curbing emissions. East Germany is a member of the 30% Club. At the Munich conference the East German delegation outlined several measures it was taking, or planned to take, to reduce emissions further and counteract damage. The expansion of nuclear power figured prominently. Daily nationwide measurements of SO_2 levels have been made since 1978, and while industrial production expands, total emissions will not be allowed to increase. Brown coal will continue to be the most important source of energy (despite the fact that it will be increasingly expensive to produce, is difficult to mine without contaminating groundwater, and reserves are limited). There have also been calls for energy conservation and more efficient energy use, the installation of district heating systems, and the use of more modern gas heating systems.

The technology for efficient combustion, desulphurisation and filtration is still at the experimental stage. Although emission reduction technology has yet to be applied in any full-scale power plants, this may be about to change. Coal gasification and coal liquefaction are being examined as ways of making energy use more efficient. At the same time, East Germany has developed its own simple desulphurisation process for brown coal: in large plants, crushed coal is mixed with 10% lime before combustion. Desulphurisation levels as high as 50-60% have been achieved and improvements are expected. One experimental plant has been in operation for two years, new plants are thought to be under construction in the vicinity of Leipzig and Karl Marx Stadt, and existing thermal power plants will be retrofitted before 1990.

Ultimately though, the determining factor in all East German emission reduction plans is likely to be economic rather than technical feasibility.

Czechoslovakia: ecological catastrophe?

Describing the state of Czechoslovakia's environment in April 1982, the newspaper *Prace* noted that the term 'ecological catastrophe' was not, in this instance, "just a turn of phrase"; it was a real possibility unless "radical measures" were taken. Czechoslovakia's serious air pollution problems have moved some Czechoslovak scientists to warn that within 16 years "part of the country could be unfit for human habitation". [86]

Czechoslovakia is the third most important industrial nation in Eastern Europe, after the USSR and East Germany. It is also the tenth biggest producer of SO_2 in the world. About 37% of its sulphur deposition comes from domestic sources. Water and air pollution levels are estimated to be 10 times higher than the world average. More than a quarter of the urban population lives in severely polluted air.

The official government view is that conditions in Czechoslovakia are under control and no more alarming than elsewhere in Central Europe, and that Western Europe is the source of two-thirds of Czechoslovakia's SO_2. The government also contests the findings of a confidential report prepared by the Czechoslovak Academy of Sciences (CSAV) entitled *An Analysis of the Ecological Situation in Czechoslovakia*, copied and released in the West in December 1983 by the Czechoslovak human rights group Charter 77. The report was intended for circulation only to top government and Communist Party officials. Charter 77 sent a copy to the Czechoslovak Premier, Lubomir Strougal, with a covering letter in which it argued that only a fraction of the country's defence expenditure would be needed to rescue Czechoslovakia from an ecological catastrophe. The money could be spent on — among other things — more energy efficient industry, reduced coal combustion and FGD.

Czechoslovak economic policy is to increase industrial production and expand energy supply, while cutting environmental management budgets. According to Charter 77, expenditure on environmental protection was cut from 1.2% of total investments in the 1976-80 five-year plan to 0.85% in the 1981-85 plan. The government denies this, and says that investments have gone up by 30%. Charter 77 pointed out that about $225 million were budgeted to be spent in the period 1981-85 on measures to avert environmental damage, while the estimated annual cost of damage was closer to $1.25-1.5 billion.

Charter 77 says the government is witholding vital information; the government says there is an open and active public debate on environmental issues. There is an element of truth in both views, because the Czechoslovak press is allowed to be openly critical of environmental conditions in the country. But public debate has so far failed to improve Czechoslovakia's dire environmental conditions.

Sources and emissions. Air pollution in Czechoslovakia is almost entirely due to SO_2. According to the Academy of Sciences report, 3-4 million out of Czechoslovakia's 15 million inhabitants are suffering directly from the adverse effects of high SO_2 levels in the air. As with East Germany, the crux of the problem is Czechoslovakia's dependence on brown coal, which governs politics and economics, and heats houses,

	1980	*1990 (Est.)*
Solid fuels (mainly brown coal)	62%	53%
Liquid fuels (oil)	26%	24%
Natural gas	9%	13%
Nuclear power	1%	8%
Hydroelectric and others	2%	2%

Figure 14. Czechoslovak energy structure. Source: ECE 1984 (Note: Official policy includes a substantial increase in nuclear capacity. There are estimates [quoted by New Scientist, *September 1984] that by 1990 a third of Czech energy will be produced by nuclear power.)*

produces electricity, and fuels industry. The most seriously polluted region of Czechoslovakia is the industrial heartland northwest of Prague, where about 80% of the country's brown coal is mined.

Czechoslovakia uses about 60-80 million tonnes of brown coal per year. The best coal is now believed to have been used up; what is left is of less calorific value, with a high sulphur and ash content. To generate the same amount of energy, larger quantities of this coal must be mined and used. With domestic and industrial energy demands constantly rising, coal is unlikely to lose its economic grip over Czechoslovakia in the short-term.

Czechoslovakia annually emits about 3.1-3.4 million tonnes of SO_2. In September 1984 it joined the 30% Club, announcing that plans to reduce emissions by 30% before 1995 would be achieved by halting industrial development in parts of the country. The announcement contrasted sharply with the claim of the Czechoslovak delegation at Munich in the previous June that it would be impossible to cut emissions at all — but that efforts would be made not to increase emissions — and with the doubts expressed by a Czechoslovak government delegation during a visit to Sweden in May about whether reductions of 30% were physically possible for any country. The sudden change of policy has been interpreted by Western observers as being the result of pressure on Czechoslovakia from its neighbours, particularly the Soviet Union, which receives a large share of Czechoslovak SO_2.

Czechoslovakia has two major regions: the Czech Lands and Slovakia. The Czech Lands (particularly Bohemia) are the most heavily industrialised — their heavy dependence on brown coal produces an average rainfall pH of 3.5. Every square kilometre of the country receives an annual average deposit of 25 tonnes of SO_2. The worst affected Czech areas are northwestern Bohemia, northern Mahren and the vicinities of major cities. The CSAV report pinpoints the region around the city of Most in Bohemia as by far the worst affected in the country. Acid damage is thought to cost $1.25-1.5 billion annually.

The forests. With about a third of its land area under forest (just over four million hectares/10 million acres), timber is a major economic resource for Czechoslovakia; matches for export are one of the biggest foreign currency earners. The CSAV report predicts future shortages of timber in the country.

No precise figures on forest damage are available, but it has been estimated (by several sources, including Charter 77) that anything from 500,000 to one million hectares (1.2-2.5 million acres) are affected. All forests higher than 800 metres (2,600 feet) above sea level are damaged. Over an area of 200-300,000 hectares (500-750,000 acres) the forests are dead, and the CSAV report predicts that half of all the woodland in Czechoslovakia will be damaged by the end of the century if present trends continue. Official figures given by the Czech delegation at Munich indicate that nearly 30% of forests in the Czech Lands are damaged.

The stages in forest dieback are similar to those in other Central European countries; 15 years ago individual spruces died and the crowns of older trees began thinning; 10 years ago groups of trees died and forest mushrooms and berries disappeared; five years ago the forests died over large, contiguous elevated areas; now the damage is spreading to valleys. Deciduous trees too are dying. The CSAV report estimates that up to 20 tonnes of lime per hectare (eight tonnes per acre) needs to be spread immediately on at least 30% of all the woodland in the Czech Lands as a temporary solution. Current Czechoslovak forestry policy is to replace conifers with more acid-resilient deciduous trees. In highland areas dead forest is apparently being clear-felled (for timber, and possibly also to prevent the spread of insects and fungi) in 'corridors' tens of kilometres wide. This has had the effect of allowing air pollutants free passage to forests further down the mountainsides, and brings the added danger of flooding after the spring snow-melt.

Surface water and groundwater. Water pollution has long been a major problem in Czechoslovakia. The effects of a threefold increase in the use of artificial fertilisers between 1960 and 1979 and the dumping of sewage into public waterways are being compounded by fallout from industrial emissions. Waste water from cities and industries is allowed to flow into rivers without purification or with inadequate treatment. Many communities have no sewage treatment plants at all, and many others have treatment plants that fall below minimum standards. Little corrective action appears to have been taken. Imported equipment is needed to build adequate treatment plants but the shortage of foreign currency makes this impossible. [87]

The burning of large quantities of brown coal, without flue gas treatment, poses the added danger of acidification and heavy metal contamination. Contamination of milk is a major cause of milk shortages, and the lack of legal requirements to monitor chemical contamination of

Jiri Polacek

Forest damage, Czechoslovakia. Czechoslovakia faces an 'ecological catastrophe' unless 'radical measures' are taken, warned a leading Czech newspaper in 1982. Timber is a major economic resource, but up to a million hectares (2.5 million acres) of the nation's forests could be dying.

food is one reason why few countries will import Czechoslovakian meat. The Academy report criticises the inadequate purification of drinking water in many places, including major cities, where it can actually be a health hazard. A West German team visiting Czechoslovakia recently reported that in the most acidified areas of the country water from shallow wells can no longer be used as drinking water. Children and pregnant women are advised to move to other regions. Bratislava is said to be short of drinking water and doctors advise mothers to give their children mineral water to drink.

The CSAV report points out that practically all mountain lakes are acidified, and even lowland lakes, which have better natural buffering capacity, are now endangered.

What is happening in Most? The urban centres of northern Bohemia are among the ugliest and most polluted blots on the central European landscape. The CSAV report notes that the region provides "a model for the way in which the environment is deteriorating throughout Czechoslovakia". *Prace* calls northern Bohemia "the burning heart of the nation". *Volksstimme*, the organ of the Austrian Communist party, recently observed that a walk among the area's huge coal craters — in an atmosphere that blocks out surrounding mountains, and with a horizon dominated by the smoking chimneys of power plants and gigantic cooling towers — gives "an idea of how capable man is of destroying the environment in his pursuit of energy".

Infant mortality in 1980 in northern Bohemia was 12% higher than the national average, and the occurrence of respiratory diseases was 120% higher than the Czech Lands average. Nowhere is the situation more desperate than in and around the city of Most, in the heart of the brown coal mining area. To clear the way for mining, 20 northern Bohemian villages sitting on top of brown coal deposits were pulled down, and the older parts of Most moved to give access to the coal beneath the city. Surface mines now stand beside the modern parts of the city. One of the largest surface mines, at the foot of the Erzgebirge, is 100 kilometres long and 20 kilometres wide (62 miles by 12 miles).

According to the Academy report, children in parts of Bohemia have 20% more red blood cells and slower bone growth than the national average, and leukaemia is more prevalent. In the Most region, infant mortality in 1980 was more than three times the Czech Lands average. Only 38% of adolescents were free of illness, a record worse even than that of the Czech Lands as a whole (57.7%). Particularly common were infections of the respiratory tract, of the skin and subcutaneous tissues, and ailments affecting muscles, bone and ligaments. The average life span for northern Bohemia as a whole was three to four years shorter than the national average.

As with many reports of acid pollution and its damage, it is not clear how large a role acid deposition plays in environmental degradation in Most. But in a region where so much sulphur-rich brown coal is burned, it must play a major role.

Local and national authorities are not unaware of conditions in the area. In fact, local residents are given special privileges. The miners have the highest salaries in Czechoslovakia, have the best supplied shops and do not have to wait as long as other Czechoslovaks for an apartment or a car. They are allowed on longer holidays abroad and receive a bonus each year for their 'loyalty'. Children are sent on special holidays abroad or to less polluted regions within the country.

Controlling emissions. At the Munich conference the Czechoslovak delegation claimed that the government had adopted new restrictions for industry, made changes in energy policy aimed at "rationalising" energy consumption, increased the import of Soviet natural gas, lowered the sulphur content of coal and oil, invested in extensive development of desulphurisation techniques (including the launch of a joint project with the USSR for the construction of a desulphurisation plant), and was accelerating the construction of nuclear power and heating plants. It is also considering scientific cooperation with Western Europe.

The Czechoslovak government was aware of the acid pollution problem, said the delegation, and was also aware that "without effective measures in other states" there was no real prospect of improvement. Official Czechoslovak policy at the moment relies heavily on expansion of the nuclear power industry. An authoritative article in the magazine *Tvorba* in 1981, entitled "Towards an Atomic Future Without Fears", suggested that the solution to the "unpleasant and increasing content of acid rain in the atmosphere" was an energy programme fuelled entirely by nuclear power. The Czechoslovak nuclear power industry has however been plagued by faults and mishaps, many of which Charter 77 ascribe to operator errors. Unlike most developed countries, Czechoslovakia has no qualms about siting its reactors close to people — all are within 10 km (six miles) of human settlements. Czechoslovakia plans to produce a third of its energy with nuclear power by 1990.

Whether an expansion of energy production is needed is debatable. Dr J. Kroh, Director of the Czech State Bank, recently pointed out that Czechoslovakia has more than enough electric power to meet its present needs, and virtually no energy conservation policy. Rates of consumption are up to 30% higher per production unit than the international average.

Poland: the world's most polluted country?

In a detailed and remarkably frank paper to the 1984 Munich conference, the Polish delegation admitted that SO_2 emissions had become a major problem in Poland. Recommended annual concentrations had been exceeded over 3% of the country, and domestic emissions were being augmented by transboundary imports. The paper confirmed reports in the Western press painting a picture of Poland as one of the world's most polluted countries. The emergence of the independent trade union Solidarity created a new awareness among Poles themselves of "the impending dangers of pollution, ecological destruction and resulting health hazards [and produced] a complete loss of faith in the belief that scientific and technological expertise and innovation" would always avail. [88]

Information about worsening conditions existed prior to the emergence of Solidarity, but was largely suppressed or censored. One 1980 government report (prepared by a fourteen-member commission from the National Centre for Environmental Protection and Development and the State Environmental Inspectorate) warned that environmental destruction in Poland was about to reach "the proportions of a national crisis".

In 1981 Solidarity handed out leaflets warning that "the biological basis of our country, our health, our children and future generations continues to be seriously endangered by the devastation of the environment in which we live... One third of the country's food is poisoned, one fifth of the population is seriously endangered by air pollution, one third of Polish rivers are completely dead, the Baltic is dying, while 78% of lakes have levels of pollution that far exceeds any acceptable standard."

The Polish Constitution states that Poland will "ensure the protection and rational development of the natural environment, which constitutes both a national resource and part of a common heritage". Since the Second World War a large body of environmental legislation, policy-making machinery, and control and research agencies has been created in Poland. But at the same time, Polish planners have been committed to rapid economic and industrial development. With industry and the economy under state control, Rafal Serafin argues in *The Ecologist*, "it was thought that the environmental problems inherent in western capitalism would be avoided".

Eugeniusz Pudlis, a Polish journalist, observes that Poland's economic crisis and the world recession have pushed environmental problems off centre-stage: "New pollution control technologies require hard cash — a commodity in short supply." [89] Despite US scientific estimates that one tonne of SO_2 emission could cost $320 in damages to crops, forests, metal surfaces, and buildings (and so could cost Poland as much as $1 billion a year), the resolution of problems such as the acute shortage of basic consumer goods continues to take precedence.

Poland nevertheless plans an emission control programme from 1991, including FGD, and fluidised bed combustion for high-sulphur coals. But the Polish delegation at Munich stressed that it was impossible to expect a significant reduction of total Polish emissions before 1990, the main limitations being "economic, technical and organisational". Poland has neither joined the 30% Club nor ratified the Convention on Long-Range Transboundary Air Pollution. At the second meeting of the Executive Body of the Convention in September 1984, the Polish delegate announced that it was economically impossible for Poland to undertake even a 30% reduction of SO_2 emissions until 1993-95.

Emissions. The predominant source of Polish air pollution is the combustion of hard coal in industries and homes. Hard coal is rich in sulphur — between 1.8% and 4%. According to official statistics, about 70% of emitted air pollutants come from industrial sources, and 15% each from transport and from district and domestic heating. Poland annually emits about 6.7 million tonnes of air pollutants, of which 73% is gas and the remainder dust. About 60% of the gas (or 2.75 million tonnes) is SO_2, the rest carbon monoxide and NO_x. The Polish delegation at Munich claimed that there had been a systematic reduction of dust pollution over several years, but gaseous emissions have been growing. At best, Polish annual SO_2 emissions in the early 1990s are likely to be about 2.8 million tonnes; at worst, they could be as high as 7.3 million tonnes. [90]

Of the 2.75 million tonnes of Polish-made SO_2, about 1.25 million tonnes settle in Poland. Imports from neighbouring countries bring Poland's total annual deposition to nearly four million tonnes. The average annual deposition rate is 10-14 tonnes per sq km (26-36 tonnes/ sq mile — well below rates in East Germany or Czechoslovakia), but this rises dramatically in the heavily industrialised region of Silesia in southwestern Poland, where average deposition is 50 tonnes/sq km/year (130 tonnes/sq mile).

Coal (mainly hard coal, with smaller quantities of brown coal) provides more than three-quarters of Poland's energy needs, and earns 15% of export revenues. Oil provides about 14% of energy needs, and natural gas about 7%. With 180 million tonnes of hard coal mined or excavated each year, Poland is the fourth largest producer in the world (surpassed only by China, the Soviet Union and the United States). Hard coal is called 'the black gold' of Poland.

Living and dying in Silesia. Hard coal has been mined and extracted in Silesia for decades. The Upper Silesian Industrial Region is the most highly industrialised part of the voivodship (administrative province) of Katowice, which is in turn Poland's largest industrial region, the source of 30% of the nation's wealth. Covering only 2% of Poland's land area, it is home to 10% of the population. Katowice is also the most polluted region in Poland, accounting for a third of Polish dust and gas emissions. Professor Stefan Jarzebski, head of the Institute of Environment Engineering of the Polish Academy of Sciences, warns that Katowice "may have the worst pollution problem in the world". Industries there emit an estimated 600-700,000 tonnes of dust and 1.77 million tonnes of gas — mostly SO_2 — each year. The average annual fall-out of dust in Poland is six tonnes per sq km per year (15.6 tonnes/sq mile/year); Warsaw receives about 250 tonnes/sq km/year (650 tonnes/sq mile/year — the maximum permitted level); but Chorzow, in Katowice, has a fall-out of nearly 900 tonnes/sq km/year (2,340 tonnes/sq mile/year), and Bytom, Gliwice and Zabrze an estimated 1,000 tonnes/sq km/year (2,600 tonnes/sq mile/year).

Rafal Serafin warns that 70% of Katowice's population lives in conditions damaging to health. He quotes studies in the Szopienice district of Katowice which reveal that 35% of children and adolescents examined had symptoms of lead poisoning, which until only recently had been classified as an 'occupational disease'. Workers suffer 25% more accidents and illness at work than elsewhere, while the general population suffers 15% more circulatory diseases, 30% more cancers and 47% more respiratory diseases than the rest of the country. In some industries 80% of the workers end up on disablement pensions. The children may be affected much earlier by the high levels of cadmium (4-16 times the admissible level). Half the country's schools for mentally retarded children are situated in Katowice.

One of the biggest sources of pollution was the aluminium smelter at Skawina (southwest of Kraków), closed in 1981 after a campaign led by the Polish Ecology Club, a group of shop stewards, journalists, doctors and academics. The smelter began production in 1954, when its annual capacity was projected at 15,000 tonnes. But production steadily increased, reaching 53,000 tonnes in 1980. As it grew, so the plant was extended; old equipment was kept going long after it should have been retired, no improvements were made in the production process, and no anti-pollution measures were taken. Annual emissions totalled 2,500 tonnes, 38% of which was in the form of gas. Westerly winds blew the emissions over the town of Skawina and the southwestern part of Kraków. The above average humidity (the annual mean is over 80%) promoted the formation of harmful concentrations of SO_2 and hydrogen fluoride that corroded stone and stucco buildings and weakened walls, roofs and metal elements.

Surface and groundwater were contaminated by toxic compounds washed by rainfall from waste deposits dumped in the vicinity of the smelter. Fluorine compounds drained the soil of the minerals that would normally neutralise them, causing poor harvests in the area. Toxic substances accumulated in crops destined for livestock fodder, and human health was endangered (industrial fluorine emissions may cause serious disturbances in the human alimentary canal).

Poland's high SO_2 levels now pose a serious health hazard to 20% of the total population [91], and by 1990 up to 27% of the population could be affected. Not even southern Polish health resorts such as Zakopane, Krynica Gorska, Rabka and Szczawnica — once famed for their reviving and curing air — are immune. Poland's League for the Preservation of Nature claim that SO_2 and other pollutants are either causing or contributing to about 600 additional deaths per 100,000 inhabitants every year.

Kraków's corroding buildings. The city of Kraków was one of the first to be included on the UNESCO list of sites of the world's cultural heritage. Its medieval old town is regarded as one of the finest surviving examples of its kind. The city square — the largest in Europe — remains much as it was in the 13th century.

But Kraków is only 65 km (40 miles) southeast of Katowice. Emissions from Katowice, added to those from Kraków's own industries, have made Kraków one of the most polluted cities in Europe, subject to frequent acid smogs. Industrial dust levels are nine times the acceptable national limit, and water trucks have to spray the central square and marketplace throughout the day, in an effort to keep the dust down. To make matters worse, Kraków sits in a humid valley, its climate often holding the effluents in a layer 80-100 metres (260-330 feet) above the ground.

The result is that the city's buildings are corroding, and their walls and roofs are being weakened. Corroded statues on the 16th century Church of Saints Peter and Paul have been taken down for safekeeping. Even the gold roof of the cathedral chapel at Wawel Castle is dissolving. Between 1975 and 1980, a total of $3 million was spent on building renovation. In Katowice itself, acid pollution has so corroded the railway tracks that trains are restricted to travelling at 40 km per hour (25 mph). [92]

The forests. Poland has about 8.6 million hectares (21.2 million acres) of forest, covering a quarter of the total land area. About 6% of the forest (500,000 hectares/1.23 million acres) is thought to be damaged, and trees over an area of 200,000 hectares (500,000 acres) are thought to have died. [93] Most of the forests (about 80%) are coniferous and therefore susceptible to acidification. Forest damage is worst in the Upper Silesian industrial region, the area around Kraków, and in the Legnica-Glogow copper basin.

Bad as the position already is, Polish scientists fear that worse is to come. The Belchatow Industrial Region, now under construction in central Poland, is expected to be a major new source of pollution. Its power plants will burn locally-excavated brown coal, and are expected to emit between 900,000 and 1.2 million tonnes of SO_2 per year, or 15% of Poland's total forecast SO_2 emissions for 1990-95. About 50,000 hectares (125,000 acres) of forest will fall within the highest danger zone for pollution. Polish environmental scientists are predicting evergreen forest losses of up to three million hectares (7.5 million acres) by 1990 — worth $1.5 billion at 1980 prices — if industrialisation proceeds as planned.

Soil acidification, affecting ploughland and groundwater deposits in turn, is expected to spread. Most Polish soils are naturally acidic podsols and so are susceptible to acidification. Crop damage would add an unwelcome burden to the Polish economy, which is heavily dependent on agriculture. Half the land is ploughland, and more than 30% of the working population are farmers.

Reducing emissions. The Polish delegation at Munich said that SO_2 emission levels would be reduced with effect from 1991 by over 30%, and NO_x emission reduction would begin in 1986. Dust reduction would be achieved by replacing old equipment with new efficient equipment, equipping sources with dust extraction systems, and modifying manufacturing technologies. Eight members of the Polish Academy of Sciences have since suggested that Poland could decrease its energy consumption, rationalise heat insulation in buildings, and develop a nuclear power programme.

About 11% of coal-burning industrial plants in Poland currently have some kind of flue gas treatment equipment, but they are not thought to be very efficient. The bulk of investments in environmental protection currently put into curbing water pollution. There is no immediate prospect of any substantive measures to curb air pollution until well into the next decade.

Hungary and the rest of Eastern Europe

Hungary, Bulgaria, Romania and Yugoslavia also feel the effects of acid pollution. Bulgaria and Romania are the least industrialised countries in the Eastern bloc, but this has not spared them; the Romanian delegation to Munich admitted that an estimated 170,000 hectares (420,000 acres) of Romanian forest have been damaged by acid rain. Forest damage has been reported in Yugoslavia too, but figures are imprecise. One estimate [94] is 450,000 hectares (1.1 million acres) of forest damaged, possibly already dead. An additional 50,000 hectares (125,000 acres) are thought to be seriously affected.

Even official Hungarian publications admit that more than four million Hungarian citizens (35-40% of the population) live with "inadmissible levels" of air and water pollution. The amount of traffic on Budapest roads has more than doubled in the past 10 years, creating frequent smogs. This has partly offset the benefits of Hungary's programme to convert residential heating from coal to natural gas, now 60% completed. The government has launched a campaign to clean up the environment generally, and has budgeted a generous 2% of GNP to the effort, but Hungarian environmentalists wonder whether this will be enough.

Over half of Hungary's air pollution originates in neighbouring countries — primarily West and East Germany and Czechoslovakia.

Conversely, more than 10% of Romania's sulphur dioxide is Hungarian in origin. Hungary also exports much of its annual SO_2 production of 1.6 million tonnes to Austria, Czechoslovakia and Yugoslavia. The Hungarian SO_2 problem is likely to be exacerbated in the coming years by a return to poor quality brown coal and lignite as energy sources. Hungary's SO_2 production may as a result reach 2.17 million tonnes. Unless these countries make a concerted effort to coordinate emission control measures or to provide funds for fuel cleaning or post-combustion control measures, the projected increase in SO_2 emissions could cause serious environmental problems. [95] It also appears that large areas of Hungarian soils are acidified, with consequent leaching of nutrients and contamination risks in groundwater.

Hungary has long been heavily dependent on imported oil as an energy source, but one of the objectives of Hungary's new energy strategy is to move away from oil, especially oil, as soon as possible. According to Jaszay and Bede [96], new processing technologies should make it possible to increase the use of existing coal resources threefold by the year 2000. Hungary has one nuclear power plant, at Paks.

Hungary's more modern power plants are equipped with electrostatic precipitators, which eliminate dust and fly ash, but not SO_2. However, the most serious sources of air pollution in the country are not power plants but motor vehicles and home heating units in cities. "In order to reduce air pollution caused by home heating systems (usually oil or coal fired burners) more than 200,000 homes are connected to district heating networks and the use of natural gas for home heating is encouraged in the capital, Budapest. Since both motor vehicles and home heating units produce large quantities of NO_x, the only way to reduce air pollution significantly in the long run in urban areas is to build large-scale district-heating systems and introduce pollution controls on all vehicles — a strategy that will take decades to implement." [97]

The East European environmental dilemma has encouraged cooperation between states in the area on the exchange of information, and talks between East and West Germany and between Austria and Hungary on shared problems. There are active citizens groups in several countries, and growing popular pressure for changes in policy. The crux of the problem will however be political disquiet about introducing environmental reforms at costs that will interfere with meeting national production goals. But the alternative — declining forest resources, impaired health, polluted rivers and acidified soils — are likely to be even more expensive in the long term.

Chapter 10

North America

As with Britain and Scandinavia, Canada provides a classic case of an upwind country (USA) producing most of the acid emissions, and a downwind country, with an environment more vulnerable to acid pollution (Canada), suffering most of the damage.

In February 1984 the Canadian government told the United States of its "deep disappointment" that US plans on transboundary pollution failed to include any action to reduce SO_2 emissions. This, said Canada, was "an unacceptable breach" of US commitments not to degrade the Canadian environment. Early in 1985, Alan Gotlieb, Canada's ambassador to the United States, was quoted as saying that the environment was "the longest-standing irritant" in relations between the two countries. [98]

Transboundary acid pollution has become one of the thorniest subjects in political exchanges between the United States and Canada. In 1980 more than 50 million tonnes of SO_2 and NO_x were released over North America, most of it emanating from the industrial northeastern United States. Over the last three decades, total emissions from the region have doubled, and those from power plants have tripled. About half the sulphates deposited over eastern Canada are thought to come from the US.

In June 1982 Canada offered to reduce its SO_2 emissions by half if the United States agreed to do the same; the US refused. Acid pollution was high on the agenda of summits between Prime Minister Pierre Trudeau and President Reagan; after the March 1985 Reagan-Mulroney summit in Quebec, Prime Minister Brian Mulroney said that the meeting had broken a three-year deadlock between the two countries, and that they had moved to a common position on acid pollution. Yet the only firm action was the appointment on both sides of envoys to examine the problem.

Mulroney emphasised that Canada's intention was to put its own house in order first, hence the launch 11 days before the summit of a Can.$300 million programme aimed at halving Canadian SO_2 emissions by 1994. But there is little sign yet that the United States is taking any concrete action to curb its emissions; officially, the Reagan administration concurs with the British view that there is too little conclusive evidence that SO_2 and NO_x emissions cause acid pollution. William Ruckelshaus, former administrator of the US Environmental Protection Agency (EPA), said in March 1985 that he did not see much prospect for a change in US policy until there were more reports of acid damage in the United States. But serious damage has already been widely reported.

United States: two out of three states affected

The major air pollution law in the United States is the Clean Air Act, introduced in 1970 with a 10-year timetable for reducing air pollution. Minimum air quality standards were to be set (and met by 1975), vehicle exhaust standards tightened, limited emissions imposed on new industrial sources, and citizens were given the right to sue industry or the government for not complying. Among the pollutants included in the act were SO_2, NO_x, ozone, hydrocarbons, particulates and lead. The EPA was made responsible for administering the act.

By 1977 it was clear that most states would not be able to meet the deadlines, so they were changed and vehicle emission standards were eased. But US controls on vehicle emissions are among the strongest in the world, and there are localised instances — in Los Angeles, for example — of reductions in photochemical smog. Violations of air quality standards have remained constant or have actually fallen; set against the growing population and industrial base, this amounts to a net fall. Human health has benefited to some extent; the Council on Environmental Quality estimated that 14,000 lives were saved in 1978 as a result of the Act's provisions.

But the good news is outweighed by the bad news: continuing or worsening smog problems in many cities, a growth in the production and use of toxic chemicals, and, above all, almost no progress in curbing acid pollution. With total annual SO_2 emissions of 24.1 million tonnes, the US is second only to the USSR on the list of the world's biggest sources. The industrial northeast — which produces most of the emissions, and with Canada suffers most of the damage — has traditionally been the focus of concern, but there is growing evidence of damage in the south, the southwest and the northwest. A total of 37 states are now known to be either vulnerable to, or have already been damaged by, acid pollution.

The Northeast

The northeast — in and downwind of the US industrial heartland of the Ohio River basin — suffers the worst damage from acid pollution. Ten states — (in order of volume of SO_2 emissions) Ohio, Pennsylvania, Indiana, Illinois, Missouri, Wisconsin, Kentucky, Florida, West Virginia and Tennessee — account for two-thirds of SO_2 emissions in the entire eastern 31-state region. [99] Rainfall with a pH of 4.0 and 4.5 is commonplace in the region, according to the EPA, and individual rainstorms with a pH below 3.0 have been recorded.

The National Academy of Sciences estimates that damage worth $5 billion or more is inflicted every year in the eastern US alone, where thin or sandy soils, and limited buffering capacity, make the soils susceptible to damage. The Office of Technology Assessment (OTA) warns that 9,000 lakes and 96,000 km (60,000 miles) of streams in the eastern US are threatened by acid pollution and acidification. In 212 lakes in the Adirondack mountains of New York state, fish have disappeared. As far west as Minnesota, 15% of lakes have been damaged. In Pennsylvania, the state government has found that 36 of 40 high mountain streams surveyed since 1962 have lost much of their buffering capacity.

Forest decline is evident on much of the high ground. Soil scientist Dr Arthur Johnson of the University of Pennsylvania, summarising the results of his and other studies of eastern forests before a 1984 Senate committee, noted that "in a large number of cases, the growth of forest trees has been substantially less than expected during the past 15 to 25 years. [In a few cases] mortality has been substantially greater than expected". [100] Acid pollution is suspected of killing red spruce trees on high mountain slopes in Vermont and North Carolina, and white pines in Indiana. In 1984, New York state launched a three-year $4.28 million project aimed at drawing up the most detailed picture yet of the acidification of ponds and lakes in the Adirondacks.

In Minnesota and New York state, health officials have advised residents to flush their drinking water pipes and restrict their consumption of freshwater fish in order to avoid consumption of toxic metals, released into the environment by acidification. Fish with mercury levels that exceed the US safety standards have been caught in both states.

In August 1984, the first law specifically designed to curb acid pollution was signed into effect in New York. The law calls for a 12% reduction in SO_2 emissions by 1988 and a 30% reduction by 1991. About one-third of the deposition in New York state is attributable to emissions within the state, but the environmental lobby hoped that the law would act as an example to other states, and ultimately to the US Congress. New York business groups are opposed to the law, arguing that it will increase electricity bills by up to 9%.

The National Academy of Sciences estimates that damage worth $2 billion is inflicted annually on buildings and monuments. In 1984 the Statue of Liberty was partially dismantled for restoration. Nearly a century in the polluted air of New York City had caused severe corrosion to its iron frame and copper cladding.

The South

The National Clean Air Coalition (NCAC) reports that rainfall in the southern states has become increasingly acidic since the 1950s [101], and dry sulphur deposition rates are projected to increase in most southern states over the next 10 years. An unofficial pH of 2.0 (the world's lowest ever) was recorded during a 1978 storm over Wheeling, West Virginia. The flush of acids that follows the spring snow-melt in West Virginia delays fish restocking in mountain streams. On Mt Mitchell in North Carolina, vegetation is unable to reproduce itself. Mature red spruce trees are losing up to 90% of their foliage, and a study of tree rings has revealed reduced growth. In the 21-year period 1962-83, tree ring growth was equal to that over the four year period 1958-61.

Studies in Virginia's Shenandoah National Park have shown that soils are losing their buffering capacity, and concentrations of toxic metals lethal to fish are leaching into streams. In Florida, as many as 4,600 lakes are considered susceptible to acidification because of the low buffering capacity of the sandy soils on which they lay. Three scientists from the University of Florida at Gainesville note that the acidity of rainfall in Florida has increased markedly in the past 25 years. They put the annual average pH level in the northern three-quarters of the state at 4.7, although readings as low as 3.8 have been returned. [102]

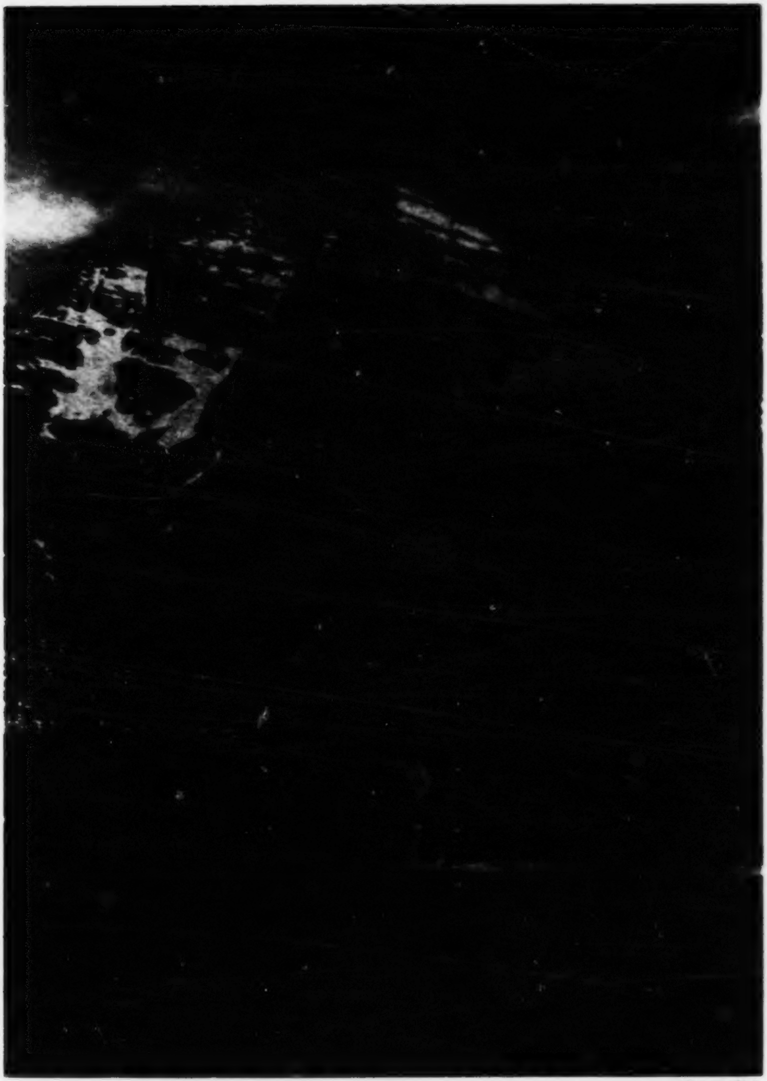
The main source of much of the sulphate deposition (up to 60%, according to the NCAC) in the 13-state southern region is the southern states themselves.

The western United States

There is evidence of actual or possible acid pollution damage or acidification in every state west of the Rockies. Virtually every mountain range in the region is sensitive, and acid deposition has already been recorded in the Rockies, the Sierra Nevada and the Cascades of Washington state, and in national parks such as Yosemite, King's Canyon, Olympic and Yellowstone.

Several recent studies have recorded acid deposition in the Rocky Mountains. A 1984 report by the Environmental Defense Fund (EDF) noted that many of the 10,000 lakes above 2,900 metres (9,500 feet) are susceptible to acid pollution. Rain measured at two sites in Wyoming and Colorado has already been found to be 10 times more acid than unpolluted rainwater. In isolated mountain lakes in Colorado, no trout have hatched for two years. [103]

EDF research indicates that about 70% of total SO_2 emissions in the Rockies come from smelters, and about 25% from coal-fired power plants.



Vernon Sigl

Aspen, Colorado, USA. Increased pollution in the western United States over the next 20 years could threaten thousands of Rocky Mountain lakes. In some Colorado lakes, no trout have hatched for two years.

EDF also warns that there are likely to be large increases in SO_2 and NO_x emissions as new sources of pollution emerge over the next 10-20 years. These will include new coal-fired power stations, synthetic fuel projects, fertiliser plants and natural gas processing plants in the Rockies themselves.

But all these are dwarfed by a large new copper smelter to be opened at Nacozari, 100 km (60 miles) from the US border. Lacking sulphur emission controls, it will become the second largest emitter of sulphur in North America, second only to the smelter complex at Sudbury, Ontario. Emissions from Nacozari, combined with plans to increase the capacity of an existing smelter at Cananaea (38 km/24 miles inside the Mexican border) will raise SO_2 emissions in the Rocky mountain air shed to levels that can be expected to cause acid damage to sensitive lakes. The Mexican smelters are expected to produce about 625,000 tonnes of SO_2 per year. If the capacity of Cananaea is tripled, as proposed, total Mexican smelter emissions would grow to 875,000 tonnes/year (more than the whole of Belgium). When emissions from planned new power plants and other energy projects are added over the next 15 years, SO_2 emissions in the region will be about double current levels.

Just as Mexican smelters pollute the US, so acid pollution and smoke from copper smelters in southern Arizona and New Mexico is being blown south across the border into Mexico at night and returning north during the day. This exchange led to a border environmental agreement signed between Mexico and the United States in August 1983, by which the US Environmental Protection Agency and the Mexican Department of Urban Development and Ecology agreed to meet intermittently. Arizona Governor Bruce Babbit is critical of the agreement, charging that it has not been followed up effectively, and noting a widely held suspicion that it was intended only as window-dressing. [104]

Ironically, it was not environmentalists but the US copper industry itself that first drew attention to the border pollution problem. In 1982 an Arizona mining company complained that the Cananaea plant operated without the expensive emission control technology forced on US firms by the Clean Air Act. When this was raised with Mexico, it retorted that a smelter at Douglas, Arizona, a kilometre inside the US border, was equally guilty. In the interests of saving jobs, the smelter had been exempted from the Clean Air Act until 1988. Meanwhile, it daily emits 900 tonnes of SO_2 into the atmosphere, and will be allowed to continue doing so until 1987, when it must either cut its emissions by 90% or close.

The Mexican government says that Nacozari will not be allowed to open without emission controls, but Mexican officials privately admit that the Mexican environmental agency may not have the power to oblige Nacozari to fit the controls, and that Mexico may be less inclined to curb emissions if the US takes no action over its smelters on the border. Most of the physical plant has been built, but controls are not included.

The outlook for the western United States could be made worse by the EPA policy of allowing US states to relax the national emission limits for smelters. If a Senate environment committee amendment that plans to postpone US smelter clean-up until 1993 is enacted, then American smelter emissions will be allowed to remain at their present levels for another eight years. That would leave smelter emissions about 50% higher than the damage threshold for at least the next nine years.

To keep total sulphur emissions below the damage threshold, the current Clean Air Act would need to be retained and the Mexican smelters would need to install SO_2 emission controls comparable to those required by most US smelters (about 90% sulphur removal). That would allow a cushion for growth that would accommodate the sulphur emissions of many of the power plants, gas processing plants and other sources of SO_2 likely to be built in the region over the next 20-40 years.

The authors of the EDF report point out that there are many similarities between the environments of the high altitude areas of the American West and those of Scandinavia. They are similar in their geology, in their lack of well-developed soils and significant acid buffering capacity, and in their lack of extensive forests. Damage comparable to that found in Scandinavia — particularly acidified lakes and soils — is a real danger in the Rockies. Long-term damage can be expected to follow if acid deposition rates remain consistently high.

California. California's acid pollution most likely results from its own emissions, since the state is not downwind from any major industrial centres. The major source areas are southern California, the San Francisco Bay area, and the San Joaquin valley. Several studies have suggested that wind can carry polluted air from southern California 500 km (300 miles) or more northeast into northwestern Arizona, site of the Grand Canyon. The winds around San Francisco tend to blow emissions southeast into the highly productive agricultural area of the San Joaquin valley. Air masses stagnating in the valley have caused high ozone levels in the Yosemite and Sequoia national parks. The yield of some crops in the San Joaquin valley has already fallen by up to 20%, but there is no clear link yet with acid pollution.

Monitoring projects have recorded some remarkably acid precipitation in California. Droplets in a 1984 winter fog in the town of Corona del Mar (south of Los Angeles), for example, had a pH level of 1.69. [105] At six sites in southern California pH values below 5.0 were recorded in 1984, and a pH of 3.1 was recorded at Pasadena. [106] Fog with acid levels comparable to concentrated sulphuric acid has been recorded in the Los Angeles basin and the San Francisco Bay area. In the San Bernardino mountains east of Los Angeles, ozone damage to trees is well documented. Harvests of ponderosa pine in the mountains have fallen by 80% since the Second World War.

The effects of acid pollution prompted the launch in early 1984 of a five-year $18 million research programme, with half the money coming from levies imposed on 35 major Californian industrial polluters. The aim of the programme is to set up 36 monitoring stations — mostly near Los Angeles and San Francisco, and in the Sierra mountains — to establish how acid pollution is formed in the state.

Recent attempts to clean up the notorious smogs of Los Angeles may be bearing fruit. The photochemical smogs — a mixture of SO_2, NO_x, ozone, lead, particulates, and carbon monoxide — are the price paid for the heavy reliance of city residents on private cars. In the Olympic year of 1984, and for the first time since ozone records began in 1955, Los Angeles passed a year without a second-stage smog alert (when ozone levels reach 0.35 parts per million for one hour, and some utilities are required to switch from coal or oil to natural gas, and some factories are required to reduce their emissions). In 1978, southern California had 23 days with second-stage smog alerts that prompted industrial shutdowns and the cancellation of school sports.

The reduction is the cumulative effect of improved vehicle exhaust controls, fuel production and industrial pollution management. When the Clean Air Act was going through Congress in the late 1960s, Californian Republican Senator George Murphy succeeded in tacking on an amendment giving California the power to impose stronger vehicle pollution controls than the rest of the country. Despite fears for the health of athletes at the 1984 Los Angeles Olympics, the fact that so many local residents took holidays or turned to public transport to avoid traffic jams produced a 3-4% fall in rush-hour traffic and a reduction in ozone levels in the city.

The Pacific Northwest. Fears have been growing that the northwestern states of Oregon and Washington — which have acid sensitive soils — may be vulnerable to acidification. The advent of acid damage would have particularly serious consequences in Oregon, which is heavily reliant on an already ailing timber industry. Most of the pollution is self-generated, but the proximity to Canada introduces an international dimension. Recent monitoring has been disrupted by the huge amounts of sulphur thrown into the atmosphere by the eruption in 1980 of Mt St Helens, but man-made emissions are thought to cause deposition in some urban areas. A March 1985 report by the World Resources Institute quotes "solid evidence" of acid deposition in the Cascades (east of Seattle) which, despite the proximity to Mt St Helens, may be linked mainly to man-made emissions. [107] Rain falling in the Puget Sound area in November 1973 had a pH of 3.8-4.8. The level of deposition was greatest downwind of a copper smelter, the emissions of which had an effect as far as 40 km (25 miles) from the plant. The plant is scheduled to close at the end of 1985.

The need for action

Upon the appointment in 1983 of William Ruckelshaus as head of the Environmental Protection Agency (EPA), President Reagan identified acid rain as one of the four priorities of the agency. Ruckelshaus was quoted as saying that "one of the most urgent problems [is] acid rain" [108], and President Reagan said: "Many of us, both here and in Canada, are concerned about the harmful effects that acid rain may be having on lakes and forests". He instructed Ruckelshaus — who he dubbed 'Mr Clean' — to "meet this issue head-on". [109] This was considered a startling about-turn by the Reagan administration, in stark contrast to the comment only seven months earlier by Anne Burford — Ruckelshaus' predecessor — that proposals for controlling acid rain were "blind groping in response to political passion". [110]

Two major scientific reports in the summer of 1983 strongly supported the need for acid pollution control in the US. The first was compiled by a White House scientific panel headed by oceanographer Dr William Nierenberg. In June 1983 the panel had recommended immediate action to curb sulphur emissions, denied that significantly more scientific certainty would be obtainable in the following few years, and emphasised that years of additional research were unlikely to indicate the need for a different control programme. It was the first time that the Reagan administration had conceded that there was a link between industrial emissions and acid pollution. Recommendations based on imperfect data ran the risk of being in error, the panel concluded, but "recommendations for inaction pending collection of all the desirable data entails even greater risk of damage". It argued that "the benefits of a properly functioning ecosystem are much more than matters of dollars and cents, and are often not appreciated by people unfamiliar with ecology". It questioned "the traditional primacy of economics in ecological affairs".

By the time the report was finally completed in March 1984, however, President Reagan had announced his budget for 1984-85, which made no mention of acid emission reductions but asked only for more money for research. Ruckelshaus had announced in January 1984 that, while funds for acid rain research would be doubled, no action would be taken on control measures, and that the administration still considered more scientific research necessary before any decisions could be made about concrete measures to cut emissions. This decision, said Ruckelshaus, was "rational, not irresponsible". He was speaking to a Senate environment committee that had approved a 1984 bill calling for an eight million tonne reduction in SO_2 emissions. Research in 1984 was to include the monitoring of nitrates and sulphates in 3,000 lakes, and in 1985 the scale of damage to forests was to be surveyed. Ruckelshaus admitted to the committee that such research should have begun as much as 10 years before. [111]

The second report, issued in June 1983 by the National Academy of Sciences, argued that SO_2 emission reductions would lead directly to a reduction in acid deposition; the Reagan administration had argued that emission reductions might not be effective in reducing acid pollution. In other words, there was a strong linear relationship between emissions and deposition. The report warned that the picture was "disturbing enough to merit prompt tightening of restrictions on atmospheric emissions from fossil fuels and other large sources such as metal smelters and cement manufacture", and that there was a strong case for immediate controls. "If we take the conservative point of view that we must wait until the scientific knowledge is definitive, the accumulated deposition and damaged environment may reach the point of 'irreversibility'."

In July 1983 Ruckelshaus said in an interview that he believed his mission entailed stopping Congress from enacting an acid pollution programme that "could create a great deal of social disruption". He also explained that it was "a question of whether the Congress [was] capable of resisting public pressure to do something about these problems. That pressure tends to be cyclical and in times of high emotion it moves toward 'Let's clean up now and worry about the costs later'." [112] Ruckelshaus also said that he strongly favoured a "sensible" acid pollution programme that would balance environmental benefits against "other societal goals".

In November 1984 Ruckelshaus resigned from his job after 18 months with the EPA. Even some of his severest critics expressed dismay over his departure; environmentalists, reported the *New York Times*, felt that whatever his shortcomings, Ruckelshaus "was genuinely concerned with protecting the environment". But this was by no means a uniform view.

There have been several attempts in the US Congress, and by individual states, to fight the Reagan Administration and enforce effective measures against pollutive emissions. New York state has been particularly active in this. In March 1984, six northeastern states (New York, Connecticut, Maine, Vermont, Rhode Island and Massachusetts) filed a suit against the Federal Government (in effect the EPA) alleging failure to curb acid pollution. The suit charged that the EPA had "ignored sections of the Clean Air Act under which states in the Middle West could be forced to reduce sulphur dioxide emissions" [113], and that inaction by EPA on acid pollution was resulting in contaminated drinking water supplies, irreversible environmental damage and continued danger to public health. It sought a court order requiring EPA to "notify offending states, mainly in the Middle West, to cut their sulphur and nitrogen emissions". [114] Ruckelshaus was named as the defendant, and charged with violating his mandatory duty to determine which states were contributing to the air pollution. The suit followed petitions by New York and Maine to EPA, in 1981, in which the two states asked for large cuts in emissions. (The petitions were formally rejected by the EPA in December 1984.)

There have been a number of acid pollution control bills before Congress in the last three years. In July 1983 a bill was introduced that would have mandated a 10 million tonne annual reduction in SO_2 emissions and a four million tonne NO_x reduction by 1995. The bill's main feature was a 'super-fund' financed by a surcharge of 0.1 of a cent per kilowatt-hour on all non-nuclear-generated electricity in the 48 mainland states. This would help pay for retrofitting the 50 most polluting electric facilities in the eastern United States with scrubbers. The bill had over 100 co-sponsors in the House, and had strong political support, but was defeated in sub-committee by only one vote.

In March 1984 the Senate Environment and Public Works Committee passed an acid pollution control plan that included a 10 million tonne SO_2 emission cut by 1994, paid for largely by several Midwestern states. The committee was dominated by senators from outside the Midwest and indications were that the bill faced a tough battle once it had left the committee. Fears that it would cause unemployment in Ohio, Illinois, Kentucky and West Virginia led to such active lobbying against the bill by the coal and power industries that the bill was never put before the Senate. In September 1984 there were at least 16 bills or amendments on acid pollution before Congress (seven in the Senate, nine in the House of Representatives). [115] Most of those advocating mandatory SO_2 reductions were based on a target of 10 million tonnes over 10 years. The Stafford-Hart bill (introduced by Senators Robert Stafford and Gary Hart in March 1983) called for a reduction of 12 million tonnes over 15 years. Interestingly, one of the bills (for an eight million tonne reduction) was introduced by Senator John Glenn from the major industrial state of Ohio.

The coal industry and electricity utilities have vested interests in blocking acid pollution control. The coal industry in the eastern US, where high-sulphur coal is mined, already has problems with high unemployment among miners in the Appalachians. Coalfield unemployment could increase further if there were more demand for low-sulphur coal produced in the western states. And like many of its European equivalents, the electricity industry claims that electricity prices would rise dramatically if the industry were forced to invest in flue-gas desulphurisation or other techniques to clean either the fuel or the gases. Western members of Congress are now becoming aware of the need for legislation to protect the West, which may help to change the political alliance favouring acid pollution control.

Canada: putting its own house in order

By 1986, Canada will have had a century of acid pollution; it will have been one hundred years since the Canadian Copper Company began the open bed roasting of copper ores in Sudbury, Ontario. By 1900 there were more than 80 such open beds, and by 1916 they were pumping 600,000 tonnes of SO_2 into the air every year. Without tall stacks, the emissions were polluting the vicinity, and local farmers were demanding action to prevent the destruction of their crops. The government response — ignoring the basic cause of the problem — was to declare 12 townships "unfit for cultivation" and settlement.

Sources of emissions. Canada today is both a major source and a major victim of acid pollution. It emits 4.5 million tonnes of SO_2 annually, making it the fifth largest national source in the world. About half Canada's sulphur deposition originates from the United States, and about half from within Canada. The industrial heartland of Ontario produces the largest emissions of SO_2 and NO_x, and feels the combined effects of its own emissions and those from south of the border.

The biggest sources of Canadian SO_2 are non-ferrous metal smelters, which account for about 45% of Canadian SO_2 (or 60% of emissions in eastern Canada). Much of the ore mined on the Canadian Shield contains a substantial proportion of sulphur (e.g. about 8% in the Sudbury basin). The smelting process applies intense heat to the ore, releasing the sulphur as sulphur dioxide.

Ontario hosts the biggest single source of SO_2 emissions in the world — the Inco (formerly the International Nickel Company) smelter complex at Sudbury (360 km northwest of Toronto), which releases nearly 650,000 tonnes of SO_2 per year (or 1,770 tonnes per day). This is actually an improvement on 1980, when it released 3,500 tonnes per day (or 1% of the world's total emissions) and on 1969, when it released 4,900 tonnes per day and public pressure finally forced government action. In 1970 Inco was ordered to reduce emissions at Sudbury in stages by 85% by 1978, and to build a 380 metre (1,250 foot) superstack to replace existing smaller chimneys.

By 1979 Inco was rightly pointing out that emissions from the stack — the highest in the world — "permitted recovery of the Sudbury environment to begin". But — as with most tall stacks — the pollution was simply dispersed further afield. Inco denied that the stack was contributing to long-distance pollution, and, having reduced its emissions by only 30% since 1970, argued that it was not economically or technologically possible to meet the 85% target. In early 1985, in a relatively sudden about turn, Inco announced that it planned to halve emissions from Sudbury by 1995, at an estimated cost of Can.$150-250 million.

One of Inco's neighbours in Sudbury — Falconbridge Nickel Mines — runs a nickel and copper smelter that is the fifth largest emitter of SO_2 in Ontario (117,000 tonnes per annum). In 1969 it was issued with a

Environment Magazine, USA

Controlling emissions, Indiana, USA. Cutting SO_2 emissions from older power plants is the key to controlling acid pollution in the central and northeast United States. This flue gas desulphurisation system was fitted to a power plant in Evansville, Indiana, in 1978.

deadline to reduce its SO_2 emissions by nearly half by 1975. In 1973 the company told the Ontario Ministry of the Environment that it could not meet the 1975 deadline, and was given a four-year extension. A representative from a local anti-pollution group noted that Falconbridge apparently had "the power to change the law. There was no consultation with or consideration of the people affected." [116]

In 1971, an SO_2 and particulate pollution monitor was set up by the Ontario environment department in the town of Happy Valley, 2.5 km (one mile) from the Falconbridge smelter. An index of 32 was the limit of acceptability on the monitor's scale. In 1972 a reading of 141 was recorded just before the monitor went off the scale, and in August 1973 the monitor reached 94. The energy and resources minister, George Kerr, concluded that it would be better to move families out of Happy Valley rather than interrupt production, and the 23 families in the settlement were relocated [117].

Acid damage. In 1980 it was reported by the Ontario environment ministry that 140 acidified lakes in the province were devoid of fish, and that a further 48,500 of Ontario's lakes (a quarter of the total) would not be able to tolerate continuing acid inputs for any extended period. Current estimates suggest that acid pollution causes anything from $180 million to $250 million worth of damage every year, and puts at risk agriculture, fishing and tourism over large areas of Canada. [118]

The spectacular and well-documented examples of acid pollution in Ontario have tended to divert attention from elsewhere, but acid damage is either actual or possible in almost every province.

- A brief two-month study in Nova Scotia in 1979 found precipitation with a pH 2.6-4.5. In 1979 a Federal Department of Fisheries scientist found that 12 rivers in Nova Scotia were dead or dying as a result of acidification, and that 40-50% of the salmon in the rivers had died that summer.
- Quebec has the largest area of land susceptible to acid pollution of any Canadian province, but few studies have yet looked into its effects. Quebec is a major emission producer, thanks particularly to the Noranda Mines smelter at Rouyn-Noranda, which annually emits 451,000 tonnes of SO_2, second only in Canada to Inco. A 1978 study by the provincial environment ministry found the average pH of rainfall in the Rouyn-Noranda area to be just under 4.0. In February 1984 the Quebec provincial government enacted regulations under which industry must reduce its annual SO_2 emissions of one million tonnes by 45% by 1990. Fines as high as $100,000 could be imposed for failure to comply. In July 1984, following direct federal government pressure, Noranda was ordered to set about reducing emissions from the smelter by 50% (on 1980 emissions of 552,000

tonnes) by 1989. The total cost will be $90 million.

- Saskatchewan is heavily reliant on agriculture, and its soils have high neutralising capacity. Neither Manitoba nor Saskatchewan are in the path of major industrial emissions (although SO_2 emissions from Alberta may pose a future problem for Saskatchewan).
- Alberta, thanks to its major oil and gas production and processing, is a major source of emissions. The development of oil sands in the northwest of the province could give rise to a considerable increase in SO_2 emissions. The provincial government has however shown little interest in action to curb acid pollution.
- British Columbia faces a possible threat from emissions from the northwest United States, but its most immediate problem is NO_x: Vancouver is the only major city in Canada with an appreciable NO_x problem.

Recent studies have given rise to concern for Canada's maple forests. In the early 1980s, there were reports from the southern Quebec counties of Beauce, Megantic, Frontenac and Arthabaska — where maple sugar production has been a major economic activity for centuries — of widespread maple tree dieback and of sugar-producing companies going out of business. An aerial survey carried out in 1984 by the provincial Ministére de l'Energie et des Ressources (MER) confirmed that isolated patches of dying maple were sprinkled throughout southern Quebec. For a province that supplies 75% of the world's maple syrup — and 90% of Canada's — the news was alarming. Ian MacLachlan, a senior official of the Ontario Maple Syrup Producer's Association, is clear about the cause: acid pollution. "Ever since [the Inco superstack at Sudbury] went up," he argues, "you can *see* the dust around here. People have to wipe it off their cars in the morning." [119]

Following an increase in the number of reports and requests for information about maple dieback, the Ontario Ministry of the Environment (OME) in July 1984 launched an acid pollution research programme that will investigate claims that acid pollution was the first link in a process that makes maples more susceptible to the effects of extreme weather, insect invasions and fungal diseases. Sam Linzon of OME suggests that a direct cause-and-effect relationship between acid pollution and maple decline will never be proven, and that it "may be the cause in a few trees, it may be exacerbating the situation in other trees, it may be killing off trees in some areas; and in other places, it won't have any bearing at all". [120] He also warns that in 10 years Canadian forests could be as devastated as West German forests are today unless urgent action is taken.

A recent study undertaken by Dr David Bates, former head of the Science Council of Canada, using data gathered over the period 1974-78, suggests that ambient sulphate levels are a cause of respiratory illnesses (such as bronchitis, pneumonia and asthma) among citizens of southern Ontario, and could have accounted for as many as 40 hospital admissions per day during summer. [121]

The US and Canada: bilateral problems, bilateral controls

On 22 February 1984 the Canadian government delivered a diplomatic note of protest to the United States, expressing its "deep disappointment" that US plans for the forseeable future failed to include any action to reduce SO_2 emissions. Canada regarded this delay as "an unacceptable breach" of US commitments not to degrade the Canadian environment, and pointed out that the US decision to limit its efforts solely to more research was a "serious step backward, one that is inconsistent with Ministerial level discussions" between the two countries, failed to "take account of US undertakings contained in the Memorandum of Intent" (signed by the US and Canada in August 1980), and was contrary to assurances given by President Reagan in a March 1981 address to the Canadian Parliament.

The protest was the low point in the history of US/Canadian attempts to reach agreement on transboundary air pollution, which date back to August 1980 and a Memorandum of Intent which established a number of working groups to undertake scientific research as the basis for negotiations toward a transboundary air pollution control agreement. Negotiations began on 23 June 1981, in Washington DC. The memorandum stated that both Canada and the United States would enforce existing legislation and regulations dealing with the emission of air pollutants until an agreement was signed. Hopes were high on both sides in August 1980, but negotiations within the framework of the memorandum had broken down by the summer of 1982, largely because Canada had suggested a mutual 50% cut in emissions which US refused.

Since then relations on the issue have been frosty. Environment Canada (the federal environment agency) and Canadian non-governmental organisations have had open political backing from the government in demanding effective measures against acid rain. Canadian bitterness has increased with US indifference, although some US politicians and environmentalists have supported and cooperated with Canada in trying to alter US acid rain policy. The essential issues in the US/Canada debate, from Canada's point of view, are that Canada receives more SO_2 from the US than goes the other way; that more environmental damage has been established in northeastern Canada than in the northeastern US; and that Canada is pushing hard for action (bilaterally and internationally), while the US is reluctant to cut emissions.

In its second report in 1984 [122], the Canadian Parliamentary Subcommittee on Acid Rain not only criticised US policy, but was also critical of the Canadian government, some provincial governments and private enterprise in Canada: "For those Canadians, including members of this Sub-committee, who have travelled to the United States to argue for more stringent controls on American polluters, Canadian government inaction and/or obstinacy with respect to domestic controls has been, quite frankly, an embarrassment."

The report observes that the scientific and economic debates on control measures have inevitably "fuelled the political and diplomatic arguments over acid rain abatement". The failure of attempts to reach an agreement with the US on acid rain control, "due principally to the intransigence of the Reagan Administration, has been a bitter setback for all Canadians... It is quite clear that the majority of our American colleagues lack the political will to tackle the problem; indeed, it has been argued by some that the essential problem with the Reagan Administration, and with certain members of Congress of both parties, is an overabundance of political will to resist any rational argument in favour of transboundary atmospheric pollution controls." [123]

The February 1984 note of protest pointed out that, as the Canadian government had said "on numerous occasions", it was because more than half the acid deposition in Canada resulted from SO_2 emissions originating in the US that unilateral Canadian action could not reduce acidic deposition to levels that would adequately protect the Canadian (and northeastern US) environment. Complementary emission controls in both countries were "absolutely essential". Damage "resulting from inaction" was already enormous and would grow worse.

A month later, at the Ottawa conference, Canadian government officials were quoted as saying that US inaction on acid rain was "one of the biggest irritants in US-Canadian relations". [124] Canadian environment minister Charles Caccia argued that Canada was "fighting for economic survival in its battle against acid rain". External affairs minister Allan J. MacEachen commented on the US attitude by calling for "a much greater commitment to the advance of civilised behaviour".

On 6 March 1985, in an announcement clearly timed to coincide with the Reagan-Mulroney summit, Canada announced that it would unilaterally halve its domestic SO_2 emissions by 1994 east of the Saskatchewan-Manitoba border, at a cost to the federal government of Can.$300 million. Emissions from non-ferrous smelters were singled out as a major target. Making the announcement, environment minister Suzanne Blais-Grenier pointed out that acid pollution was costing Canada Can.$250 million per year, and that fishing, tourism and agriculture were at stake over an area of 2.6 million sq km (one million square miles). A sum of Can.$25 million had been immediately earmarked for the development of new and cheaper emission control systems.

The plan has been agreed by only seven of Canada's provinces: Saskatchewan, Alberta and British Columbia have stayed out. Critics charged that Alberta was more interested in energy development than the environment. An official of the provincial environment department retorted that the agreement had no application to Alberta, that sulphate deposition was lower in the province than the national average, and that Alberta's soils were not as sensitive to acid deposition as some others.

Announcing Canada's decision, Blais-Grenier said that Canada "must seek a compatible course of action in the United States". The sub-committee had argued earlier that Canada must argue "from a position of moral strength. The moral authority of our argument for emission controls in the United States will increase in direct proportion to the extent to which we reduce similar pollutants in Canada."

The controversy between the United States and Canada has so far centred largely on SO_2 emissions, but Canadians are aware that nitrogen oxides are a major element and that US exhaust gas standards from motor vehicles are far ahead of those in Canada. The Canadian sub-committee observed that the Canadian regulatory position was "an anomaly, is environmentally harmful, and causes acute political embarrassment to Canadians in discussions with US legislators and officials". The acid pollution control strategy of Ontario Hydro, for example, one of the country's largest, non-private emitters of SO_2 and of large quantities of NO_x, "is imprecise and undependable". Ontario Hydro is a Crown Corporation, the largest and most powerful electrical utility in Canada, situated in Canada's industrial heartland. It has "the responsibility to lead the way in [pollution] control, to set an example for other industries to emulate. That it has not done so, but instead has forfeited its leadership role, is at best unworthy and, at worst, irresponsible." Ontario Hydro emits around 600,000 tonnes annually of SO_2 and NO_x. Canadian environmentalists are also only too aware that per capita SO_2 emissions in Canada are twice those of the US, and that the US has about 100 scrubbers on its coal-fired power plants whereas Canada has none.

In the March 1985 announcement of SO_2 reductions, Canada also announced plans to reduce NO_x and introduce new vehicle emission standards (equivalent to those in the US), to be effective from 1 September 1987. Unleaded petrol is already available in Canada, and a complete switch is planned for about 1988, when catalytic converters will have to be fitted to all new vehicle models.

Brian Mulroney's optimistic comment at the end of the March 1985 summit that the three-year deadlock between the two countries had been broken seems fanciful. The appointment of envoys by the US and Canada to investigate the situation and report back within a year was met with scepticism from environmental groups on both sides of the border. Michael

Perley of the Canadian Coalition on Acid Rain observed that it was "a clear message that the US is not willing to address the problem", and argued that the appointment of the envoys was "clearly an admission of defeat" for Mulroney, because it held no US commitment to reduce emissions. There was also dismay that Canada had chosen as its envoy Bill Davis, the former Premier of Ontario. Colin Isaacs of the Pollution Probe Foundation described Davis as "the Canadian premier who did the least on acid rain". Davis himself was cautious about what could be achieved, noting that the initiative was unlikely to produce dramatic results.

At the time of going to press, there was little prospect of the Reagan administration agreeing to any substantial controls on emissions, leaving Canada to continue on its unilateral course for the foreseeable future.

Chapter 11

Japan

Fifteen years ago, Japan was a symbol of all that was most extreme about developed societies. Spectacular technological progress, and economic growth that was twice the average of other OECD countries, paved the way for a second industrial revolution. Output soared, and exports reached every corner of the globe. Energy consumption grew by 390% between 1960 and 1973, and the number of cars on Japanese roads grew from 610,000 to more than 22 million.

A switch from coal to oil in the 1960s made Japan largely dependent on imported fuel, much of it high-sulphur oil from the Middle East. In major urban centres such as Osaka and Tokyo, road vehicles became a major source of air pollution, adding to largely uncontrolled emissions given off by Japan's burgeoning industry. Air pollution reached levels almost unsurpassed anywhere in the world. Japanese cities were choked by smog; their citizens suffered irritated eyes, sore throats, impaired breathing and worse. Over 100 people died or suffered agonising damage to their nervous systems when mercury pollution contaminated fish in Minamata Bay, and others died or were crippled from cadmium pollution.

Realising that environmental and human damage on such a scale was an unacceptable price to pay for economic development, Japan introduced increasingly rigorous pollution controls during the 1970s, with the result that it now has one of the toughest and most comprehensive bodies of anti-pollution legislation in the world. It also has one of the most comprehensive SO_2 and NO_x monitoring networks. By 1981, SO_2 was being recorded at nearly 1,600 monitoring stations, and NO_x at 1,200 stations.

Reduced energy consumption, switches to low-sulphur fuels and the introduction of emission controls have produced remarkable results. After peaking in 1967, annual average SO_2 concentrations had fallen by more than 75% by 1981. [125] In 1980, 1,546 monitoring stations (98.4% of the stations in Japan) reported success: the SO_2 standards for the area they measured had been met. The benefits were visible. At one time Mt Fuji could rarely be seen from Tokyo, 100 km (60 miles) away; now it is a frequent sight.

But Japan's emission figures have yet to be correlated with information on acid deposition, about which there is a surprising lack of knowledge.

Acid mists were reported in the early 1970s, as was corrosion to metals, concrete, leather and fabrics, and damage to rice crops, orange groves and pine trees. [126] There is no substantive evidence yet of soil or water acidification in Japan, or of damage to forests. Japanese soils may in addition have greater neutralising capacity than many of those in Europe or North America.

In late 1984, the Environment Agency announced the establishment of a panel of experts to study Japanese acid pollution. The panel, which will monitor rainwater at 14 sites, is expected to report in 1988.

Reducing emissions. Japan may once have had more serious air pollution problems than any other country, but it has since led the way in developing emission control technology and setting air quality standards. SO_2 controls were first implemented in 1962 with a law which restricted smoke and soot concentrations in designated areas. In 1968 the Air Pollution Control Law was passed, imposing restrictions on SO_2, NO_x, particulate and other emissions. In 1969 environmental quality standards were established for sulphur oxides, heralding the introduction of environmental quality standards for several pollutants.

Large SO_2 sources in polluted areas have a fee imposed on them based on their emission levels — part of the proceeds are used to treat patients affected by air pollution. [127]

The first SO_2 reductions were achieved mainly through increased use of low-sulphur oil, which in the 1970s was almost as cheap and readily available as other kinds. But during the energy crises of 1973 and 1978, Japan's need to diversify its energy supply led to the increased use of oils of higher sulphur content, and of coal.

The pollutive effects of these higher-sulphur oils were offset by Japan's heavy oil desulphurisation programme, launched in 1967. By 1981 there were 12 direct desulphurisation units in operation, and 44 indirect units, with a total capacity of nearly 230 million litres (48 million gallons) per day. The sulphur content of heavy oil was more than halved between 1967 and 1981.

Investment in emission controls grew rapidly in the period 1965-75. In 1965 pollution control accounted for about 3% of the total equipment outlay of Japanese industry. By 1975 — the peak year — the proportion had risen to 17% (the petroleum industry leading the way with an expenditure ratio of 34.7%). [128] In the third quarter of 1974 alone, more than $1 billion was spent on pollution control equipment.

Flue gas desulphurisation (FGD) equipment has now been fitted to more than 1,360 mostly oil-fired power plants (compared to about 200 plants in the United States), although most of this was made possible by Japan's rapid economic growth; the bill for the SO_2 control programme in the early 1970s came to more than $4 billion, but industry was able to bear the cost. Where FGD has been fitted to coal-fired plants, an SO_2 removal ratio of 90-95% has been achieved, and the equipment has proven its reliability. Moreover, Japanese scrubbers produce saleable by-products, such as gypsum and sulphuric acid. The use of FGD was at first promoted by a shortage of sulphur materials; now production has outstripped demand.

The first pollution controls for road vehicles came in 1966, with restrictions on carbon monoxide emissions. Regulations on NO_x and hydrocarbons followed in 1975, along with controls on NO_x emissions from stationary sources. Japan is the only country that requires NO_x controls on stationary sources, and all major fossil fuel-fired power stations must install NO_x controls aimed at cutting emissions by 73%. [129] Low-NO_x burners, fuel conversion and denitrification of flue gases have been the main means used; in 1980 there were 140 denitrification plants in operation in Japan, using mostly selective catalytic reduction.

The first regulations for car exhaust gases were laid down in 1974, and since 1978 Japan has had the most stringent rules in the world. The fitting of catalytic converters to cars from 1975 resulted in a 10% increase in the cost of new cars and a decline in car sales, but it also produced a 90% reduction in exhaust emissions. Average annual concentrations of NO_x have however remained about the same (0.026-0.028 ppm) since 1974. Increased future use of coal will be accompanied by strict NO_x and SO_2 emission regulations. Large power plants in polluted areas must have a staged combustion technique of some kind and flue gas denitrification must be able to meet the emission standards.

Japan may well have prevented significant acid pollution damage from its own SO_2 and NO_x emissions, but there are now fears that China may be exporting acid emissions to Japan. There are no firm data to support this yet, but the presence upwind of the world's third largest producer of SO_2 could yet cancel out some of the benefits of Japan's pollution control programme.

Chapter 12

The Third World and the Arctic

Acid pollution was until recently thought of as a North American and Northern European problem, and is still commonly seen as exclusively a developed country problem. It is rarely associated with less industrialised developing societies, where water pollution is often seen as a more immediate threat. Yet the potential for serious acid pollution exists in, near and downwind of the industrial centres of many developing countries. Evidence of acid pollution — or conditions that could cause acid pollution — has already been found in south and southeast Asia, in the Middle East, in southern Africa, and in Latin America.

A joint project between the UN Environment Programme and SCOPE, a committee of the International Council of Scientific Unions, was launched in 1984 to investigate the degree to which acidification has already become a problem in tropical countries, to assess the potential for the occurrence of harmful future effects if SO_2 and NO_x emissions were to increase, to identify susceptible areas in relation to soils and ecosystems, and to investigate the need for monitoring the status of the environment (including air, water, soil and vegetation) in tropical countries so that baseline values can be established and possible changes detected at an early stage. Countries that may be studied include Brazil, Mexico, India, Kenya, Malaysia, Nigeria, China and Venezuela.

Third World energy demand and consumption

The major source of domestic energy for most developing countries is fuelwood; in some, including Malawi, Tanzania, Ethiopia and Mali, it accounts for more than 90% of total energy consumption. The Third World as a whole accounts for a small proportion of global commercial energy consumption, but the proportion is growing: in 1973 developing countries accounted for 16% of the total world energy consumption; in 1983, 22%. By 1995 the proportion could have risen to 27%. The 12 largest energy consumers account for more than two-thirds of total Third World commercial energy consumption. China accounts for about 30% of the Third World total (and for two-thirds of coal consumption), and Brazil, India and Mexico together account for another 20%. Oil is likely to remain

	1973		*1983*	
	Whole world	*Developing countries*	*Whole world*	*Developing countries*
Oil	2,798	429	2,794	634
Coal	1,668	411	2,097	649
Natural gas	1,066	82	1,329	148
Hydro, nuclear	381	58	706	123
TOTAL	5,913	980 (16%)	6,926	1,554 (22%)

Figure 15. Commercial primary energy consumption (in million tonnes of oil equivalent). Source: BP statistical review of world energy June 1984.

the most important commercial fuel, with motor transport, light industry and urban household consumption the major consumers. Most of the technology involved is imported from the developed world.

Energy conservation is often suggested as a major route to reductions in air pollution emissions in developed countries, where the continual renewal of equipment makes a 50% cut in energy consumption per unit in energy efficient industry within the realms of possibility by 1995. But in the Third World, where older machinery and appliances are in use for much longer, comparable savings are unlikely. Lack of capital is the major constraint. As developing countries develop an industrial base, the share of heavy industry in manufacturing output is likely to expand. The development of heavy industry without the added expense of emission control technology will mean more pollution.

Coal is not expected to be a major Third World energy source, except in the relatively few coal-rich countries. Demand for coal is limited because it is not competitive for small industrial boilers (boilers producing less than 50 tonnes of steam per hour make up the majority of those in use in developing countries), and many power stations are too small to switch economically from oil to coal.

Air pollution in Third World cities

Third World cities frequently suffer much higher levels of air pollution than cities in developed countries, a consequence of rapid industrial growth without effective planning and regulation systems. [130] Despite new legislation, the creation of state environment agencies, and the lobbying of non-governmental groups, there is little sign of sustained government action to curb pollution. NO_x and ozone are already critical elements in many major Third World urban centres with heavy traffic, and are likely to become much worse. While the Third World rural population barely doubled between 1920 and 1980, the urban population grew ninefold. [131] In 1950, 17% of the Third World's population lived in cities; by the year 2000 the figure is expected to be nearly 44%. In 1980, eight of the world's 15 largest (and most polluted) urban centres were in the Third World, including Mexico City, São Paulo, Shanghai, Beijing and Rio de Janeiro. [132] As the size of cities increases, so will the use and concentration of road traffic. Ratios of vehicle ownership to population in some of the cities of richer Third World nations are comparable to those in developed countries. The introduction of unleaded petrol in developing countries is unlikely in the forseeable future, so the concentration of airborne pollutants will increase accordingly.

Although the Third World (excluding China) had only 11% of the world's industrial production in 1980 [133], its industry tends to be highly concentrated, by region and by country, and growth has been rapid. More than 35 Third World nations recorded annual average industrial production growth rates of 5% or more during the 1960s or 1970s. [134] To add to the problem, the tightening of pollution laws in developed countries has meant that multinational corporations have been tempted to transfer so-called 'dirty industries' — including metal smelters — to developing countries with less stringent regulations. Japanese and North American companies have for example transferred production to countries like Taiwan, South Korea, the Philippines and Thailand. Remarkably few studies have been made of SO_2 and NO_x levels in Third World cities, but frequent and regular smogs suggest that levels are likely to be high in the most polluted cities.

Concentrated urban pollution in the Third World is beginning to have the same kinds of effects on surrounding countryside as Northern cities. A study of pollution in China by Professor Vaclav Smil of the University of Manitoba suggests that reported cases of damage to crops downwind from Chinese industrial centres are "most certainly just the proverbial tip of the iceberg". [135] This comment could apply equally to other Third World nations experiencing rapid industrial growth. For instance, damage has been reported to the once important rice-growing Samsoon plains in South Korea from power and petrochemical plants and copper and zinc smelters. [136]

China: major acid pollution potential

As the world's third largest consumer of primary commercial energy and emitter of SO_2, and the second largest producer of hard coal, China faces greater risks of acid pollution than any other Third World country. Although confirmed incidents of wet acid deposition are as yet infrequent (a reflection largely on the lack of comprehensive monitoring), air pollution is a major hazard in the north and northeast, and in most major urban centres. The source of 80% of China's air pollution is the inefficient combustion of low-quality coals — in power plants, industrial boilers, iron and steel plants, refineries, chemical plants, steam locomotives, ships, and millions of households. [137]

China derives about 70% of its primary energy needs from coal, consuming about 600 million tonnes annually. Annual coal production increased more than 20 times between 1949 and 1982. Present annual production stands at an estimated 660 million tonnes, and present consumption produces about 12-15 million tonnes of SO_2 annually (second only to the USSR and the US). If production increases as projected, SO_2 emissions could reach 18 million tonnes per year by the end of the century.

Although small domestic stoves account for 60% of China's coal consumption, homes use cleaner coal than industry, so domestic heating actually produces only 35-40% of total SO_2 emissions. "A high dependence on coal will always be a major source of emissions," observes Professor Smil, "but the situation is made worse by the poor preparation of Chinese coals before combustion and by very inefficient conversion technologies". The sulphur content of Chinese coal is low — 0.4-1.5% — but, unlike most major coal-producing countries where coal is washed before use, only 17% of Chinese coal is cleaned.

Inefficient combustion means that, whereas 60% of fuel is converted into useful energy in Japan, and 40-55% in North America and Europe, the fuel conversion efficiency figure for China is just 30%. The concentration of energy consumption in a few major urban centres creates further problems. Beijing relies on coal for three-quarters of its energy needs, consuming eight million tonnes per year. The major consumers are power plants, 10,000 small boilers in offices and factories, and about a million household stoves. The stoves and boilers are highly inefficient, and emit about 20 kg (44 lbs) of SO_2 per tonne of coal burned, or 200,000 tonnes per year.

Because these emissions come mainly from low chimneys, the pollutants concentrate close to the ground, especially during autumn and winter thermal inversions. In the absence of emission controls, observes Professor Smil, this provides a perfect setting for the repetition of acute air pollution episodes such as that in London in 1952. Hazy winter days have become a characteristic of northern Chinese cities.

One of the major effects of pollution is on health. Emissions of SO_2 and other pollutants are thought to be linked, for example, with the higher than average incidence of lung cancer in Chinese cities: 17-31 per 100,000 people, compared to 4-5 per 100,000 in rural areas. [138] One estimate [139] is that air pollution causes an annual loss of more than 3.5 million working days, and 6,000 premature deaths (mainly among newborn babies and elderly people with chronic heart or lung diseases).

Some of the largest chemical industries and oil refineries are located in Lanzhou, a new industrial city in northwestern China. Although there is a danger of acid precipitation, the air in northern China contains high concentrations of alkaline particles (desert dust, among others) and measurements of the rain have shown values of pH 7.0-7.5. The soils in these parts are generally alkaline, except in peat areas. Nevertheless in Lanzhou's Xigu district, pollution has destroyed fruit trees in nearby villages, has caused date plants to stop producing fruit, and is stopping pumpkins from maturing.

Beijing is known for its high concentrations of particulates in the air, about half of which is desert dust and half is fly ash and smoke from coal combustion. Measurements in the city in 1979-80 found that rainwater was not abnormally acidic, but there were high concentrations of sulphate and nitrate ions. Investigators concluded that the concentration of suspended matter in the water neutralised the acids. In 1983, however, it was reported that Beijing rainwater was slightly acid (pH 5.0-5.5). [140] Acid rain monitoring began in Shanghai and Songjiang counties in March 1980, and noted Shanghai's first recorded acid rain storm in September 1981.

Chinese municipal authorities have ruled that heavy industry should no longer be allowed to expand in major cities that are popular tourist spots, such as Beijing, Hangzhou, Suzhou and Guilin, where industry is already concentrated and environmental quality is poor.

Southern parts of China are likely to be at high risk from soil and water acidification in future, according to Arne Jernelov of the Swedish Environmental Research Institute. [141] Soils and surface waters, especially south of the Yangtze River, are generally acidic and the soils are poorly buffered. The particle content of the air is much lower and the pH of rainwater is 4.5-5.5. The lower levels of sulphur emitted by domestic coal burning is being offset by a rapid industrialisation programme which demands increased amounts of energy. There is a clear risk of acidification of soils and surface waters.

Plans to expand coal-fired electricity generation are likely to increase the risks of acid pollution. A proposed concentration of power stations in Shaanxi, China's richest coal province, could create major SO_2 and NO_x emissions that would be carried south/southeast in winter and north/northwest in summer, respectively affecting the farmlands of the North China plain and the Nei Monggol pastures. Planned power stations at Jilin would produce summer emissions that would be carried over Da Hinggan, China's richest boreal forest. [142]

Controlling pollution and the formation of acid deposition in China promises to be difficult. There are no cheap, readily available alternative sources of commercial energy, and the costs of replacing outdated combustion equipment or installing emission controls may be prohibitively expensive. Energy is being used more efficiently in some areas (industrial output in the 32 largest cities rose by 10% in 1980, while primary energy use fell by 4.6%), but this will need to be applied far more widely to have any appreciable effect.

Southeast Asia: road traffic problems

Southeast Asia is rapidly industrialising, and its energy demands are rising. Coal-fired power plants in the region are expected to expand from their current 2,000 MW capacity to about 25,000 MW by 1990. Such an expansion would raise coal consumption in the region from three million tonnes today to 60 million tonnes over the next decade. Uncontrolled combustion of coal with an average sulphur content of 1% would lead to annual SO_2 emissions of 1.2 million tonnes in a region where the soils are moderately to highly susceptible to acidification.

A more immediate problem is the rapid increase in the volume of road traffic in almost all major cities in the region. Traffic is thought to account for 92% of the air pollution in Kuala Lumpur and 75% in Metro Manila, for example. Cities in the region share several characteristics that suggest that air pollution will become worse, courting the risk of dry acid deposition. For instance, the commercial centres of Malaysian cities are known to be several degrees warmer than the surrounding countryside, a phenomenon that creates 'heat islands' which, in calm conditions, produces a circular airflow above the city. Hence the sulphur and nitrogen oxides, hydrocarbons and other pollutants created by traffic can be recirculated within a city locality, posing a potential threat to human health.

The ability of the air above a city to disperse and dilute pollutants depends partly on wind speed and partly on the mixing of different air layers. The air over most southeast Asian cities is still and stable, giving them little ventilation and creating ideal conditions for the build-up of air pollutants. The US National Air Pollution Potential Forecasting

Program has set a critical minimum ventilation limit for the dispersion of pollutants. In Jakarta, six in every 12 months are below the limit, in Bangkok eight out of 12 months, and in Singapore 11 out of 12 months; Kuala Lumpur never goes below the limit.

Given the stable atmospheric conditions and long hours of sunshine in many southeast Asian cities, levels of smog and ozone production — and hence of acid deposition, particularly dry deposition — are liable to rise. Dr Sham Sani, a geographer at Malaysia's Kebangsaan University, warns that air pollution problems in Metro Manila and other cities of southeast Asia are likely to be worse than those in some North American cities. The Philippines National Pollution Control Commission warned in 1979 that industry and road vehicles in Manila (which harbours 63% of the country's industrial firms) discharged substantial quantities of air pollutants. [143]

Hong Kong faces particular problems. One of the most densely populated areas in the world, it is home to five million people but is not zoned for different activities. Industry rubs shoulders with residential areas. Industry, overpopulation and millions of motor vehicles cause extreme air pollution; levels of SO_2, NO_x, CO and lead are high. An estimated 400 kg (880 lbs) of pure lead, in the form of particles, are emitted daily over an area of just a few square kilometres.

Fear of acidification in Thailand has encouraged the Office of the National Environment Board to start an air pollution research programme. There are close to 900,000 vehicles on Thai roads, most of them in the Bangkok area. Dry deposition could pose a major threat of Bangkok's architectural heritage. Air pollution is already serious in many Thai cities, especially Bangkok, but no reliable data on acidification are yet available.

Malaysia: growing urban pollution

Air pollution is already a major health hazard in many of Malaysia's main urban centres. According to the Director General of the government's Environment Division, the highly urbanised Kelan valley, which includes Kuala Lumpur, has two to three times the pollution level of major US cities. [144] As early as 1977 the Ministry of Science, Technology and Environment estimated that Malaysia was annually emitting 635,000 tonnes of pollutants, and that the total was increasing at 10% annually. The source of 45% of the pollutants is road traffic. The number of vehicles on Malaysian roads has been rising rapidly: from 670,000 in 1970 to 2.6 million in 1982 in Peninsular Malaysia. Badly maintained engines and the high lead content of petrol make the emissions worse. Annual NO_x emissions are likely to be at least 200,000 tonnes and lead emissions 2,000 tonnes. In Kuala Lumpur, road vehicles are thought to account for about

92% of pollutants in the air. [145] In 1975, emission controls were introduced under the Road Traffic Ordinance, but they applied only to diesel-powered vehicles.

Clean air regulations introduced in Kuala Lumpur in 1978 appear to have had little effect. Readings from air-quality samplers have revealed suspended particulate densities of between 118 and 313 microgrammes per cubic metre, well above the World Health Organization (WHO) recommended maximum level of 40-60 microgrammes. [146] Ozone levels rise from near zero in the early morning to 0.06 parts per million between midday and early afternoon. WHO recommended limit is 0.06 ppm for a maximum of one hour.

The amount of traffic on the road, combined with an abundance of sunshine and stable atmospheric conditions, court the danger of increasingly severe photochemical smog in Malaysian cities, and hence of dry acid deposition and ozone damage. Kuala Lumpur receives about the same amount of solar radiation per year as Los Angeles, a city infamous for its smog.

Industrial emissions are a more localised problem. A major industrial polluter is the Datuk Keramat smelting plant in George Town, on Penang Island. The Malaysian Meteorological Department has run a limited monitoring programme since 1976, using standard World Meteorological Organisation procedures. Monthly samples of rainfall in Petaling Jaya (outside Kuala Lumpur) and Tanah Rata (in Perak) returned pH readings of 4.4-4.8 and 4.9-5.5 respectively. [147]

Under the Environmental Quality Act of 1974, a Division of Environment (DoE) was set up under the Ministry of Science, Technology and Environment to regulate environmental quality. It has the power to issue regulations and orders on pollution control and to issue licences to regulate the discharge of wastes. A number of regulations have since been issued, but the DoE is required only to see that pollution levels do not exceed 'acceptable' levels, a definition which Sahabat Alam Malaysia (SAM — Friends of the Earth Malaysia) believes makes a mockery of the concept of environmental management. SAM charges that the DoE "simply ignores the issue of pollution", and that environmental quality will continue to remain an issue of low priority "as long as politicians and government officials still think that emphasis on environmental management will affect foreign and local investment and economic growth." [148]

India: threats to the Taj Mahal

India is a major coal producer and consumer. Production in 1982 was 125 million tonnes and is expected to increase to around 325 million tonnes in 1995. Annual SO_2 emissions tripled from the early 1960s to reach 3.2 million tonnes in 1979. Indian coal has a generally low sulphur content (less than 1%), but the projected increases in coal consumption in the next 10 years could push SO_2 emissions closer to seven million tonnes. NO_x emissions are also likely to rise with the growth in road traffic and the operations of fertiliser plants, refineries, and petrochemical and other industries.

Coal-fired thermal power stations account for nearly 65% of India's electricity supply. Although the coal used in the stations is low in sulphur, it has a high ash content (25-40%). The older plants are fitted with mechanical dust collectors that generally operate at about 70% efficiency. Newer plants have electrostatic precipitators which can remove up to 99% of dust if properly maintained. But the breakdown of precipitators in the Bhatinda power station in the Punjab resulted in 1,200 tonnes of fly ash being emitted into the atmosphere every year. In 1982, *India Today* magazine reported that the town of Bhatinda (which received no power itself from the plant) lay under "a permanent blanket of smoke; fly ash coats every surface and a good deep breath is likely to wind up a racking cough".

The Delhi-based Centre for Science and Environment (CSE) warned in 1983 that air pollution, "after engulfing the large cities in India,... has begun to hurt the residents of small towns and once sleepy villages where thermal power stations and large industries are now being located". [149] CSE observed that while urban communities have pressure groups and officials to whom protests can be made, effective protest in villages can take longer to emerge.

India's Sixth Five Year Plan (1980-85), while noting the country's advantages (low-sulphur coal, relatively few automobiles, and a rainy season that is an effective air scrubber), points out that air pollution is becoming severe in major cities like Calcutta, Bombay and Delhi, and levels of SO_2 and particulate matter in some major cities exceeds permissible limits set by WHO. One recent report [150] argues that every major Indian city suffers chemical air pollution. Half of Delhi's air pollution is thought to come from domestic fuel burning. [151] CSE pointed out that India's uncontrolled industries and badly maintained automobiles may be fewer in number, but they rival those in the West in their pollutive capacity. Reducing air pollution levels in Indian cities, it suggests, could involve popularising the use of efficient stoves, setting and enforcing emission control standards for motor vehicles, limiting traffic in congested or ill-ventilated streets, and carrying out air quality surveys.

A senior executive of Graphite India argued that pollution "is the price society must pay if it wants modern society to thrive — if we close down, society will have to pay a higher price [than mere pollution]". India — like many developing countries — faces a struggle between demands for economic growth and an improved standard of living, and demands for a healthy living environment with a minimum of pollutive side-effects.

Southern and eastern parts of India contain soils susceptible to acidification. One Indian scientist, Professor D.N. Rao of the Banaras Hindu University, warns that agricultural yields could drop by 17-30% depending on the level of future emissions. Professor Rao has reported damage to plant life in the Mirzapur district in Uttar Pradesh. A case study from a sulphuric acid plant has shown that the estimated loss of mango crops alone amounted to thousands of rupees. When emission control equipment — including acid mist eliminators — was installed, it added 0.2% to the production costs and cut concentrations of gaseous pollutants by 90%. Mango trees in Bombay have been damaged by air pollutants; a study by the Institute of Science in Bombay found that mango trees along road sides were damaged considerably; up to 30% of the tree leaves died, and trees in areas surrounding the Hindustan Petroleum Refinery were destroyed.

The problems facing the Taj Mahal illustrate the threat to India's cultural heritage. In 1982, a major oil refinery was opened outside Mathura City, just 40 km (25 miles) upwind from the Taj Mahal in Agra, and upwind from other monuments in Fatehpur-Sikri, Mathura and Brindavan. The refinery processes 6.2 million tonnes of crude oil annually. There were fears from the outset that the pollution caused by the refinery would slowly destroy the Taj Mahal, although government officials denied the possibility. An Italian consultancy firm brought in to advise on the environmental consequences of the refinery concluded that SO_2 emissions would be insufficient to damage the Taj, and that the existing discolouration of marble and sandstone in monuments in the vicinity was due to algae and fungi rather than pollutants. On the basis that the threat to the Taj could be minimised by controlling emissions from other sources in the area, two thermal power stations were closed and coal-burning railway locomotives were replaced by diesel powered engines.

Professor J.M. Dave of the School of Environmental Studies at Jawarhalal Nehru University in New Delhi, predicted that the refinery would annually emit 25-30 tonnes of SO_2, 100-150 tonnes of carbon monoxide, 60-100 tonnes of hydrocarbons, 100 tonnes of NO_x and trace metals like vanadium, nickel, cadmium and chromium, most of which would be blown by the north-westerly winds in October to March from Mathura to Agra. Professor Dave warned that increased acidity would "definitely damage the marble of the Taj irreparably over a period of 50 to 100 years. The delicate carved projection may crumble even earlier, being converted into gypsum".

Mark Edwards/Earthscan

Calcutta, India. Chemical air pollution is a problem in every major Indian city. There may be fewer cars than in Western cities, but poor maintenance makes them more pollutive. Limiting traffic in congested or poorly ventilated streets could be one answer.

Dept of Foreign Affairs, South Africa

Air pollution, South Africa. South Africa's oil-from-coal plants help make the Witwatersrand (around Johannesburg) one of the biggest sources of SO_2 emissions in Africa. Acid pollution threatens an area bigger than Luxembourg.

AFRICA

With few concentrations of heavy industry, relatively few heavily populated urban conurbations, and deriving most of its energy needs from non-commercial fuels such as firewood, acid pollution is generally a distant concern in most of Africa. But evidence of acid pollution has nevertheless been found near concentrations of industry in South Africa and Zambia.

South Africa

South Africa is already an industrialised nation and a major coal producer and consumer. Hard coal is the main source of energy, half being consumed in electricity generation. About 85-100 million tonnes of cheap coal is produced annually, causing estimated SO_2 emissions of about one million tonnes. [152] About 80% of the coal is burned within 200 km (125 miles) of the Witwatersrand (around Johannesburg) where the bulk of South African heavy industry is situated. The area includes the oil-from-coal plants run by state-owned Sasol, the largest company of its kind in the world. Sasols's Secunda plant is reported to emit 480 tonnes of SO_2 per day. [153] The area also supports power plants, iron works, chemical industry, paper and pulp industry, manufacturing industry and coal mining.

The area at greatest risk from acid deposition is the Eastern Transvaal highveld, which includes the Kruger National Park. The threat will grow if a planned expansion of coal-fired power stations is carried out in the region. In 1985 about 2,250 tonnes of SO_2 per day will be emitted over the Eastern Transvaal. It has been estimated that due to the stable atmospheric conditions, in the winter in particular, 80% of the air pollutants will stay within an area of some 3,000 square kilometres (1,150 sq miles), which will be subject to more that 220 tonnes of SO_2 alone per sq km. The Witwatersrand emissions will also contain NO_x and other pollutants. No hard data are yet available about rainwater acidity or possible effects on rivers and groundwater, but measurement of rainwater is planned and the Council for Scientific and Industrial Research is planning a five-year study.

The first signs of corrosion to buildings in Johannesburg are now being reported [154], and archaeologists at the University of the Witwatersrand report that centuries-old rock engravings and Iron Age relics are suffering damage.

Zambia

Commercial copper production in Zambia began in 1931. Although it has

Zambia Consolidated Copper Mines Ltd

Copper smelting, Nkana, Zambia. Copper accounts for 91% of Zambian exports, but pollution in the Copperbelt has already damaged local plant life and could threaten agriculture, freshwater fishing, and forestry over a wide area.

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only really grown since the Second World War, the air pollution created by sulphur dioxide from smelting was already a problem in the late 1930s. By 1979, copper accounted for nearly 91% of Zambia's exports. Mining and refining is concentrated in the most heavily urbanised area in the country — the eight towns that make up the Copperbelt — where nearly 60% of all urban dwellers live.

Copper ores contain a high proportion of sulphur, and the smelting process emits about 1,250 tonnes of SO_2 per day. Some is recovered to produce sulphuric acid, and there are plans both to recover more and to change processing techniques to reduce emissions, but acid deposition has already been recorded. Much of this is dry deposition that falls in the vicinity of the smelters, having an adverse effect on the growth of vegetable and fruit plants. Some meteorologists hold that the poor visibility frequently recorded at the airports at Kitwe and Ndola is a direct result of gaseous emissions, but this is disputed. Zambia Consolidated Copper Mines Ltd argues that meteorological conditions favour rapid dispersal of stack emissions and thermal inversion layers never last more than a few hours, so SO_2 emissions never build up to hazardous levels. [155]

A short monitoring programme carried out in Luanshya and Mufulira by Roan Consolidated Mining in 1980 found that levels of SO_2 in the atmosphere increased markedly during the dry winter months. Professor N.P. Perera of the University of Zambia believes that the mining companies have been "remarkably responsible" in their attitudes towards pollution. "In the absence of any legislation and at a time of financial difficulty they have made considerable efforts to evaluate the existing problems and introduce alternate production techniques." Nevertheless, he warns, SO_2 emissions remain a long-term problem over a wider area than the vicinity of smelters, and could pose a hazard to the freshwater fishing industry, agriculture and forestry. [156] The Zambia National Conservation Strategy, published in January 1984, reached similar conclusions, and noted that local vegetational damage was already evident where sulphur compounds were generated by copper and zinc smelting.

Kenya, Nigeria, Zimbabwe and Cameroon

Although no data are available from Kenya on air pollution and its possible environmental effects, Kenya may be included in the projected UNEP/SCOPE study on acidification in the tropics. Nigeria is still an agricultural country, but the rising value of oil reserves (which account for 90% of export earnings) has expanded the industrial sector to 15% of GDP. If oil reserves are used as a vehicle for domestic development, and industrialisation leads to more domestic combustion of oil, the risk of damage to soils and crops will grow. Alarming levels of carbon monoxide and/or airborne lead have been noted in Lagos and Ibadan in Nigeria, and alongside busy roads in Zimbabwe [157] suggesting a potential for higher than average levels of nitrogen oxides in some localities.

Experiences in Cameroon not only show that smaller cities are not immune from the effects of air pollution, but are representative of the problems faced by many other developing countries. Douala (the capital) and Yaounde (the chief port and main industrial centre) have estimated populations of close to half a million and 300,000 respectively. In common with most cities, their air pollution stems from industrial emissions and a concentration of motor vehicles. The effects of the pollution are heightened by the lack of planning needed to separate people from polluting industries. It is the lower income groups — who cannot afford to buy or rent even the cheapest legal housing and have to resort to building illegal shelters on sub-standard land that may be in the path of industrial emissions — who tend to suffer the worst effects of the pollution. [158]

LATIN AMERICA

Data on actual or potential acid pollution in Latin America are variable, but there are enough confirmed instances of isolated pockets of heavy pollution (notably in and around major cities) to suggest that acid pollution is a real danger. A recent unofficial survey by Associated Press found that acid pollution was a "serious problem" in Brazil, Mexico and Chile, and that it had been reported in Argentina and Peru. Leading environmentalists warn of the dangers: "It's very serious", says Paulo Nogueira Neto, head of Brazil's environment agency. "In some areas the damage is obvious, but it could be occurring in other places that we don't know about."

There are three short-term barriers to action. Firstly, acid pollution is not a public issue and is not generally perceived as being a problem. It is such a new phenomenon (in the Latin American context) that many people, even government officials, have never heard of it. Second, the lack of reliable data undermines the case for action. Third, the priorities of development and the economic burden of often massive foreign debts make pollution control — in the eyes of many governments — a minor concern. A 1982 report by the São Paulo Federation of Industries in Brazil observed that Brazil must "choose between pollution and recession". [159]

Brazil

Brazil has some coal reserves, and coal consumption is rising by about 10% per year. Brazil's most heavily industrialised areas are in the southeastern states of Sáo Paulo, Rio de Janiero, Minas Gerais, Paraná and Rio Grande do Sul. Soil samples from the eastern parts of São Paulo state have shown extremely low pH values (3.7-4.7). Cubatao, near São Paulo, is one of the most polluted industrial areas in the world, perhaps rivalled only by the industrial centres of Poland and Czechoslovakia. Situated in a valley, Cubatao's air contains 1,200 microgrammes of industrial particles per cubic metre, twice the amount considered lethal by WHO. Thirty-three factories daily emit 1,000 tonnes of SO_2, NO_x,

Sebastio Salgado/Earthscan

Cubatao, near Sao Paulo in Brazil, is one of the most polluted industrial centres on earth. Its air contains twice the level of industrial particles considered lethal by the World Health Organization. Fish die in its polluted water, trees turn to dry skeletons, and more babies are born deformed here than anywhere else in Latin America.

Sebastio Salgado/Earthscan

CO, hydrocarbons and dust. Some 15,000 people live in Cubatao, most of them low-wage workers.

The industries have no emission controls and their low production costs and cheap labour make their products more competitive on the world market. Development began in the early 1950s with four large multinational companies; today there are 19. Fish die in the reddish water, trees are reduced to dry skeletons, human health suffers, and 80% of the flora is gone. In 1981 it was revealed that 17 out of the 3,400 newborn children in Cubatao died from anacephalia (a rare disorder that causes children to be born without a brain or other parts of the body). The normal rate of anacephalia in Latin America is one in every 5,000 newborn babies. In Cubatao it was one in 200.

In August 1984 the São Paulo state environmental office announced a four-year programme for reducing air pollution in Cubatao by 90%, at an estimated cost to the industries involved of $150 million. [160]

Air pollution is now 'normal' in most Brazilian cities. In addition to Brazil's soil acidification, large areas of Brazil consist of naturally acid soils. For example, 75% of the Amazon Basin has acid, infertile, well-weathered soils deficient in plant nutrients. The aluminium content of these soils is so high that it can be toxic to plants. Any acid deposition that followed in the wake of development would have serious ecological implications for soils in the basin. One major potential threat comes from the development of aluminium smelting, supported by investments from Brazilian firms and companies from Canada, Italy, Japan, the Netherlands, the United States and West Germany.

Acid deposition and the risk of ozone damage in rural areas could undermine the extension of cropping. This has been made possible in the past by adding large quantities of lime and fertilisers. Two or three crops a year are now possible in some areas of the Amazonas, raising hopes that the pressure on the tropical moist forests can be eased, particularly from slash-and-burn farmers currently compelled to burn vegetation and fertilise the soil with the few nutrients contained in the ash.

Venezuela

Venezuela is the fifth largest oil producer in the world, annually producing over 110 million tonnes of crude oil. Oil and oil products together account for 96% of export earnings. Most of the oil — which is generally high in sulphur — comes from the area around Lake Maracaibo in the northwest. Large reserves have also been discovered by the Orinoco. Industries — including refineries and petrochemical plants — are concentrated in the north and northwest. In the east, where the Orinoco and Caroni rivers meet, a major new city, Cuidad Guayana, with a heavy industry centre is being constructed.

In 1983, the director of environmental protection in the Venezuelan environment ministry, Roberto Yoshiba, warned that there was potential for acid rain in Venezuela. [161] Nitrogen oxide emissions from road traffic present the biggest problem at the moment; Caracas alone has more than 500,000 cars. Sulphur dioxide emissions are below recommended international limits, but this could be changing. Yoshiba warned that there were several 'risk areas' where industries were using sulphur-rich fossil fuels. These included thermal power stations at Planta Centro and Tacoa in the far west of Venezuela and a petrochemical complex at Moron (west of Caracas).

Another future source of emissions is the heavy crude treatment plant planned for the Orinoco oilfields, which will start processing 125,000 barrels of oil a day in 1988, posing a potential threat to the nearby Uverido forest reserve and the town of Ciudad Bolivar, 30 km (19 miles) away. The state petroleum company, Petroleos de Venezuela, claims that sulphur dioxide emissions from the plant would not be sufficient to affect Uverido. Yoshiba is less certain, but financial cutbacks in the environment ministry have meant that he has not had the funds to carry out adequate monitoring programmes.

Given the sensitivity of soils in the north and the concentrations of cities and industry there, there are also risks of environmental damage from acidifying emissions in these areas. The large-scale extraction of tar sands at Orinoco could contribute to the future acidification of Venezuelan soils and waters. Venezuelan tar sands, like those in Canada, Colombia and the US, reportedly contain as much petroleum as the oil fields in the Middle East, but the economic and environmental costs of extracting oil from tar sand are high.

Chile

In Criciuma, the heart of Chile's coal-producing area, two-thirds of the region's rivers, lakes and reservoirs are reported to be 'highly acidified' and one local official estimates that 80% of hospital admissions are for respiratory problems. An agricultural official warns that within five years there will be "a major tragedy" unless action is taken. [162] Crop losses and corrosion to buildings are reported from the vicinity of the central Chilean town of Ventanas, site of a state-owned copper smelter and coal-burning power station. A local farmer told the newspaper *La Tercera* that "since the smoke started coming out, just about everything around here has died". Further north, there is concern for the effects on the Chilean wine industry of emissions from a copper smelter owned by a subsidiary of the US oil company Exxon.

Adalberto Rios/Centro de Ecodesarrolo

Mexico City's mayor has warned of 'collective hysteria' unless dramatic measures are taken to control the city's air pollution. In February-May, visibility is often reduced to three or four city blocks.

Mexico

Mexico City is one of the most polluted cities in the world, so much so that in October 1984 Mayor Ramon Aguirre Velazquez warned of "collective hysteria" unless dramatic controlling measures were taken. [163] The City's position in a valley surrounded by mountains creates a temperature inversion in the hot months of February to May that combines with heavy city traffic to produce a brown, noxious photochemical smog, containing ozone and other oxidants, that reduces visibility to three or four city blocks.

Three-quarters of Mexico's three million cars and most of its commercial vehicles are found in the Mexico City area. City planners predict that there could be four million cars on city roads by 1988. In addition, the population has grown from 1.7 million to 17 million since 1940. Mexican petrol consumption is rising accordingly: by 59% between 1979 and 1982. Trees are already dying along the most heavily travelled corridors in the city. Emissions from the city's 130,000 factories add to the daily output of 11,000 tonnes of particulates into the air. For seven months of the year, winds are too weak to disperse these and other emissions. According to a study by the Autonomous University of Mexico, contamination levels "are likely to cause irreparable damage to the health of residents". Bronchial infections and pneumonia are on the increase. A $1.5 million air monitoring system was launched in 1982 by the Ministry of Urban Planning and Ecology.

Mexico has estimated oil reserves of 40,000 million barrels, and crude oil accounts for 71% of export earnings. Newly discovered oil reserves in Mexico, Venezuela and the Caribbean are believed to be in the same order of magnitude as known reserves in the Middle East. The Mexican oil fields are mainly concentrated on the eastern coast, in the Mexican Gulf, on the US border and south of Veracruz. Prevailing winds in Mexico indicate that pollutants from refineries and industrial centres on the east coast may well be deposited in agricultural areas (coffee, sugar cane) on the coast and east of Mexico City. The Yucatan Peninsula in particular has soils that are likely to be susceptible to acidification.

THE ARCTIC

Recent research has revealed the first signs of air pollution north of the Arctic Circle. Concentrations of SO_2 at levels comparable to those found in southern Norway have been reported by Norwegian scientists. In Svalbard (Spitsbergen), the northern archipelago of Norway, high values of sulphur compounds have been recorded, and on the Greenland ice cap man-made sulphate deposition is believed to exceed natural deposition by two and a half times.

'Arctic haze' was first described in 1979, when atmospheric scientists set up equipment in Barrow, Alaska. [164] They collected particles that bore a chemical resemblance to pollutants produced thousands of kilometres to the south. Subsequent research has suggested that, in the winter and spring, pollutants can travel 5,000 km (3,000 miles) and more from the industrial areas of Europe and North America, producing a pervasive haze in the Arctic during the winter and early spring.

Air sampling undertaken by Canada's Atmospheric Environment Service at Mould Bay and Igloolik resulted in filters turning 'flannel gray' and 'sooty black' during winter and spring. Sulphate, vanadium, and other trace elements appeared in quantities too large to be accounted for solely by sea salt or soil dust particles present in the atmosphere. A separate study in Barrow by the US National Oceanic and Atmospheric Administration found that the quantity of pollution in the aerosol increased when the wind blew from the north, suggesting that the pollution did not have a local origin. A third study, by Kenneth Rahn of the University of Rhode Island, suggested that of the total winter-spring aerosol mass (excluding water), about half was sulphate, organic matter, soot and other pollutants.

By comparison with heavily polluted urban areas, levels of pollution in the Arctic atmosphere are not high, but winter-spring concentrations of sulphates in the Arctic are about the same as average winter levels in the northeast United States. According to a report in *Science* [165], researchers now agree that Arctic air can become polluted during winter and spring because there is little precipitation at that time to remove the pollutants from the air as it moves northwards. There is some debate about which areas provide most of the pollutants, but the evidence to date suggests that this changes with air circulation patterns. The central Soviet Union is the major source in early winter, western Europe the major source in mid-winter, and eastern North America the major source in the spring.

Recent monitoring flights suggest that Arctic haze can cause restricted visibility over areas the size of the North American continent. In early 1983, scientists representing Norway, Denmark, Canada, the US and West Germany flew systematically over the Arctic, recording the density and extent of the haze. Russell Schnell from the US National Atmospheric and Oceanic Administration commented: "The pollution was not only thick, but amazingly thick. We didn't even have to look down [from the plane]; just looking out, we saw brownish haze." [166]

According to Einar Joranger of the Norwegian Arctic Project, there are fears that the fragile Arctic ecosystems could suffer even from low concentrations of the trace elements, zinc, lead, cadmium and mercury that have been found. The discovery of notable levels of hydrocarbons in Arctic air has prompted an Arctic research team based at the Ny Alesund Polar Institute to begin collecting mosses and freshwater fish for testing. Much research is now being carried out to learn more about Arctic haze and its possible effects, both on the Arctic itself and possibly on the global climate.

Conclusion

Acid pollution is one of the most familiar and most newsworthy environmental issues of the moment. It is also one of the most misunderstood.

That certain kinds of air pollution produce wet or dry acid deposition is no longer seriously disputed. That the combustion of fossil fuels is the major source of the pollution is agreed. That a variety of emission control technologies are available is well-known. But the effects of acid pollution — and the relative role of other factors, especially in forest dieback and surface water acidification — are still hotly debated. And the precise mechanisms by which these pollutive effects are achieved are still unclear, raising inevitable questions about the best way of preventing harmful environmental impacts.

The categorical division of countries into polluters and polluted, the anger of the victims and the excuses of the perpetrators, and the often emotive level of public debate, have all complicated the issue.

* 'Acid rain' is indiscriminately and wrongly used as a blanket term to describe several different (but related) forms of air pollution associated with the combustion of fossil fuels.
* The interest in SO_2 has until recently drawn attention away from the role of nitrogen oxides, ozone and other pollutants.
* The obsession with acid damage in western Europe and eastern North America has obscured the almost universal threat of acid pollution. It is a real or potential problem almost wherever fossil fuels are burned in any quantity.

The search for a way out of the maze is complicated by inconsistent monitoring methods, differences in the interpretation of data, and an absence of coordinated research between countries. Governments differ on even the most fundamental questions, such as the setting of SO_2 threshold levels above which damage occurs. Scientists differ over the exact relationship between acid pollution and environmental damage. The debate is often tinged with nationalism, with scientists falling prey to assessments coloured by national interests.

The causes and consequences of acid pollution are complex, and the environmental repercussions are only beginning to be understood. Much is suspected but much less is confirmed. Most scientists involved would probably agree with US lawyers Gregory Westone and Armin Rosencranz, who comment that the acid pollution problem is "in many respects so subtle, and the research so new and complex, that a clear picture of its nature and precise impacts will probably not be available for many years". [167] Nevertheless, most scientists and politicians are broadly agreed on the urgent need for action, before such a "clear picture of its nature and precise impacts" is available.

The confusion is used by some governments and industries as an excuse for delaying preventive action. The technology needed to reduce pollutive emissions from industry and road vehicles is available and well-known, but until the costs of acid damage can be quantified in hard economic terms, many governments will continue to prevaricate. The costs of introducing emission controls can be calculated with a fair degree of accuracy, but the costs of *not* introducing controls are more difficult to calculate, and much more open to subjective assessment. Where such calculations have been made, there is little agreement over the criteria used.

One of the thorniest issues is that the countries that are the biggest sources of emissions often feel fewer acid effects than recipient countries downwind. The costs of controlling emissions are high, and tend to be highest in the countries that produce most SO_2 and NO_x. Many governments see emission control as involving major financial outlays for the benefit mainly of other countries. The degree of national concern about acid pollution is directly proportional to the level of damage in that country. The application of solutions is often obscured by national self-interest.

Britain's Earth Resources Research group points out that inaction over emission controls is widely seen as a low-risk option in Britain because it avoids heavy investment in abatement technology. But they also warn that this is potentially a "high-regret" option, because it relies on the hope that the reported effects of acid pollution are "exaggerated, temporary or are caused by other factors which may or may not be controllable". [168]

A focus on SO_2 to the exclusion of other pollutants threatens the efficacy of emission controls, because there may be little to be gained from tackling one pollutant in isolation. Control policies aimed at reducing emissions from power stations, from smelters and from road vehicles need to be coordinated within an overall emission control strategy.

Even if some governments still deny that acid pollution is a problem justifying immediate action, emission controls make immediate and quantifiable economic sense on other counts. Energy conservation would not only reduce pollutive emissions by reducing the demand for electricity generated by thermal power stations, but would reduce demand for fuels, increase energy-use efficiency, and reduce national energy bills.

Action against pollutive emissions is further complicated by the fact that many governments consider energy policy a strictly domestic issue, of no concern to other countries. This has particularly complicated East-West discussions on acid pollution control. Environmental questions are only a recent addition to the agenda of international political and economic meetings. Since their solution often demands substantial unilateral action that does not always provide quantifiable economic or social returns, governments are reluctant to act.

Whatever the doubts, several major scientific committees and international organisations, and even a number of governments, are agreed that enough is known or suspected about acid pollution to warrant action. The European Community, the UN Economic Commission for Europe, the UN Environment Programme, the OECD, the US National Research Council, the British House of Commons environment committee, and the 21 or more government members of the 30% Club add up to a powerful lobby in favour of action. But the reductions promised by 30% Club members are only the first step; bigger reductions and greater expenditure are still needed. Three of the biggest producers of emissions — the United States, Britain and Poland — are not yet members of the Club. And conditions are ripe for increasingly serious acid pollution throughout the industrialising Third World, particularly in China.

Acid pollution is a classic instance of economic and industrial development proceeding at the expense of the environment. It may well be the most universal and most pressing transfrontier environmental issue of the century, providing a test case for the lip-service paid to environmental management by more and more governments over the past decade.

The solution depends on closing the gap between principle and practice, on understanding the economic benefits of sound environmental management, and on balancing short-term interests against long-term policy. The costs of pollution control are high, but the costs of acid pollution may be even higher.

References

1. *New Scientist*, London: 13 September 1984.
2. Environment Canada: *Downwind: The Acid Rain Story*, Ottawa: 1982.
3. Chandler, W.: *Energy Productivity: Key to environmental protection and economic progress*, Worldwatch Paper No. 63, Washington DC: January 1985.
4. House of Commons Environment Committee: *Fourth Report: Acid Rain*, London: HMSO, 1984.
5. Quoted by Richard Ayres in testimony before House Subcommittee on Health and Environment, 20 March 1984.
6. Figures from World Energy Conference.
7. Altschuller, A.P. and McBean, G.A.: *The LRTAP problem in North America: A preliminary overview*, US-Canada Research Consultation Group on Long Range Transport of Air Pollutants, 1979.
8. Galloway J.N. and Dillon, P.J.: *Effects of acid deposition: the importance of nitrogen*. Stockholm: Ministry of Agriculture, Stockholm Conference on the Acidification of the Environment, Stockholm: 1982.
9. Greenfelte, P.: *Oxidised nitrogen compounds in long range transported air masses*, Swedish Water and Air Pollution Research Institute, 1979; and Brimblecombe, P. and Stedman, D.H.: "Historical evidence for a dramatic increase in the nitrate component of acid rain", in *Nature*, 298, 1982.
10. National Research Council: *Acid deposition: Atmospheric processes in Eastern North America*, Washington DC: National Academy Press, 1983.
11. Charlson, R.J. and Rodhe, H.: "Factors controlling the acidity of natural rainwater", in *Nature*, 295, 1982; and Galloway J.N. Likens, G.E., Keene, W.C., and Miller, J.M.: "The composition of precipitation in remote areas of the world", in *Journal of Geophysical Resources*, 11, 1982.
12. *ENDS Report* 101, June 1983.
13. Dudley, N., Barrett, M., and Baldock, D.: *The Acid Rain Controversy*, London: Earth Resources Research, 1985.
14. National Research Council, op. cit.
15. Oppenheimer, M. and Yuhnke, R.E.: *Sulfur pollution: Strategy for preventing acid pollution damage in the intermountain air shed*, Boulder, Colorado: Environmental Defense Fund, 1984.
16. Environmental Resources Limited: *Acid rain: a review of the phenomenon in the EEC and Europe*, London: Graham and Trotman, 1983.
17. Federal Ministry of the Interior: *Report of the Causes and Prevention of Damage to Forests, Waters and Buildings by Air Pollution in the Federal Republic of Germany*, Bonn: 1984.
18. Nihlgård, Bengt: "The Ammonium Hypothesis: An additional explanation to the forest dieback in Europe", in *Ambio*, Vol. 14, No. 1, 1985.
19. Environmental Resources Limited, op. cit.
20. OECD: *The costs and benefits of sulphur oxide control*, Paris: OECD, 1981.
21. Strauss, W. and Mainwaring, S.J.: *Air Pollution*, London: Edward Arnold, 1984.

22. Harvey, Harold: "The acid deposition problem and emerging research needs in the toxicology of fishes", in *Proceedings of the Fifth Annual Aquatic Toxicology Workshop,* Hamilton, Ontario: November 1978.
23. Environmental Resources Limited, op. cit.
24. Timberlake, L.: "Poland — the most polluted country in the world?" in *New Scientist,* 22 October 1981.
25. UN Economic Commission for Europe: *Report on the effects of sulphur compounds on materials, including historic and cultural monuments,* Geneva: 1982.
26. Yocom, J.E. and Baer, N.S.: "Effects on materials" in *The acidic deposition phenomenon and its effects,* US EPA Critical Assessment Review Papers, Vol. 2, Washington DC: 1983.
27. Timberlake, L., op. cit.
28. Yocom, J.E. and Baer, N.S., op. cit.
29. Gerhard, J. and Haynie, F.H.: *Air pollution effects on catastrophic failure of metals,* US EPA-650/3-74-009, Research Triangle Park, North Carolina, 1974.
30. Timberlake, L., op. cit.
31. Research at the Swedish Corrosion Institute, reported in *Land,* Sweden: 20 January 1984.
32. Wetstone, G.S. and Rosencranz, A.: *Acid rain in Europe and North America: National responses to an international problem,* Washington DC: Environmental Law Institute, 1983.
33. Ibid.
34. *ENDS Report* 109, February 1984.
35. Kilgroe, J.D.: "Coal cleaning for sulfur dioxide emission control", US EPA, presented at acid rain conference, Springfield, Virginia, April 1980.
36. CONCAWE — *SO_2 emission trends and control options in Western Europe,* The Hague: 1982; and Elam, N. and Trichem Consultants Ltd: *Present and future levels of sulphur dioxide emissions in Northern Europe, prepared for the Swedish Ministry of Agriculture,* Stockholm, 1979.
37. Ibid.
38. US Environmental Protection Agency: *Sulfur emissions: Control technology and waste management,* Washington DC: Office of Research and Development, May 1982.
39. *ENDS Report* 112, May 1984.
40. Wetstone, G.S. and Rosencranz, A., op. cit.
41. OECD: *Control technology for nitrogen oxide emissions from stationary sources,* London: HMSO, 1983.
42. *ENDS Report* 119, December 1984.
43. OECD: *Costs of coal pollution abatement,* London: HMSO, 1983.
44. Leach, G. et. al.: *A Low Energy Strategy for the United Kingdom,* London: IIED, 1979.
45. Chandler, William U., op. cit.
46. *New Scientist,* London: 9 February 1984.
47. OECD: *The OECD Programme on Long Range Transport of Air Pollutants,* Summary report, Paris: OECD, 1977.
48. Wetstone, G.S. and Rosencranz, A., op. cit.
49. Swedish Environmental Protection Board, based on research by the Corrosion Institute.
50. Wetstone, G.S. and Rosencranz, A., op. cit.
51. Ibid.
52. Landin, Bo: "Finland: acidification diagnosed", in *Acid News,* No. 4, October 1984.
53. Federal Ministry of the Interior, West Germany, op. cit.
54. Dudley, N., Barrett, M. and Baldock, D., op. cit.
55. UK Review Group on Acid Rain: *Acid deposition in the United Kingdom,* Warren Spring Laboratory, 1984.

56. House of Commons Environment Committee, op. cit.
57. *New Scientist,* London: November 1984.
58. House of Lords Select Committee on the European Communities: *22nd Report: Air pollution,* London: HMSO, 1984.
59. Nature Conservancy Council: *Acid deposition and its implications for nature protection in Britain,* London: NCC, 1984.
60. Dohmen, G.P. et. al.: "Air pollution increases *Aphis fabae* pest potential", in *Nature,* Vol. 307, 1984.
61. AERE-R11382, *Ambient ozone measurements at Harwell, Jan-Dec 1983,* London: HMSO, 1984.
62. *New Scientist,* London: 13 September 1983.
63. *The Times,* London: 10 October 1984.
64. House of Commons Written Answers, from Lynda Chalker, Under Secretary of State, Cols 431-2, 5 March 1984.
65. *New Scientist,* London: 15 September 1983.
66. Bow Publications: *A role for Britain in the acid rainstorm,* Bow Publications, 1984.
67. Wetstone, G.S. and Rosencranz, A., op. cit.
68. Heyse, Tine: "The acidification situation in Belgium", in *Acid News,* No. 2, March 1984.
69. Pallemaerts, Marc: "Belgium sits on the fence", in *Acid News,* No. 5, December 1984.
70. Agren, Christer: "Denmark: 30% reduction in sulphur emissions proposed", in *Acid News,* No. 2, March 1984.
71. Reichfelt, Professor, in *Landschaft & Stadt,* Vol. 15, 1983, quoted in *Acid News,* No. 2, 1984.
72. *International Herald Tribune:* 4 January 1984.
73. *The Times,* London: 18 July 1984.
74. Chase, William: "Ireland: Hoping for strong winds", in *Acid News,* No. 5, December 1984.
75. Direction des Eaux et Forets: Entwicklung der neuartigen Waldschaden in Luxembourg, 1984.
76. Quoted by *La Vanguardia,* 29 April 1984.
77. *La Vanguardia:* 23 October 1984.
78. Swedish delegation in Geneva, and Dagens Nyheter, Sweden.
79. Bundesamt für Forstwesen: Ergebnisse der SANASILVA Waldschadeninventur, 1984.
80. Engels, F.: "Part played by labour in the transition from ape to man", in *Dialectics of Nature,* Moscow: Progress, 1976.
81. *Newsweek:* "A dying landscape", 14 January 1985.
82. Quoted in Elsworth, Steve: *Acid Rain,* London: Pluto, 1984.
83. Quoted in *New York Times,* 24 April 1984.
84. Soviet report to the Munich Conference, June 1984.
85. In *Skogen* (Forest), Sweden, March 1984.
86. Quoted in *Der Spiegel* No. 12, 1983.
87. *New Scientist,* London: 27 September 1984.
88. Serafin, Rafal: "The Greening of Poland", in *The Ecologist,* Vol. 12, No. 4, July/Aug 1982.
89. Pudlis, E.: "Poland's Plight: Environment damaged from air pollution and acid rain", in *Ambio,* Vol. 12, No. 2, 1983.
90. Ibid.
91. Ibid.
92. Timberlake, L., op. cit.
93. Pudlis, E., op. cit.
94. Quoted by Elsworth, Steve, op. cit.

95. Jaszay, T. and Bede, G.: "Energy and environment in Hungary", in *Ambio* Vol. 13, No. 2, 1984.
96. Ibid.
97. Ibid.
98. *Toronto Globe and Mail:* 15 March 1985.
99. Rhodes, Steven L.: "Superfunding Acid Rain Controls — Who Will Bear the Costs?", in *Environment,* Vol. 26, No. 6, July/August 1984.
100. *New York Times:* 26 February 1984.
101. Agle, Elizabeth C.: Remarks to Southern States Energy Board Conference on Acid Rain, 18 October 1984.
102. Brezonik, P.L., Edgerton, E.S., and Hendry, C.D.: "Acid precipitation and sulfate deposition in Florida", in *Science,* 30 May 1980.
103. Yuhnke, R.E. and Oppenheimer, M.: *Safeguarding acid-sensitive waters in the intermountain West,* Boulder, Colorado: Environmental Defense Fund, 1984.
104. *Los Angeles Times:* 24 August 1984.
105. Aplet, J.A., Shikiya, M.C., Broadbent, J. and Nelson, E.: *Acid Deposition in the South Coast Air Basin* (draft). California Air Resources Board, South Coast Air Quality Management District, El Monte, California, June 1984.
106. *New Scientist,* London: 9 February 1984.
107. World Resources Institute: *The American West's Acid Rain Test,* Washington DC: WRI Research Report No. 1, March 1985.
108. Quoted by *7Dagar,* Sweden, March 1984.
109. O'Donnell, F.: "Acid rain controls — Is there a 'sensible' compromise", in *Sierra,* November/December 1983.
110. Ibid.
111. *New Scientist,* London: 9 February 1984.
112. O'Donnell, F., op. cit.
113. *New York Times:* 21 March 1984.
114. *New York Times:* 3 December 1984.
115. National Clean Air Coalition, Washington DC.
116. Carter, D. and McCauley, W.: *The Sudbury Pollution Problem: Socio-Economic Background* (unpubl.), Ottawa: Department of the Environment, 1974.
117. Ibid.
118. *International Herald Tribune:* 8 March 1985.
119. Norton, Phillip: "Decline and Fall: Something is killing Canada's maple forests", in *Harrowsmith,* No. 60, April/May 1985.
120. Ibid.
121. Bates, D.V. and Sizto, R.: "Relationship between air pollutant levels and hospital admissions in southern Ontario", in *Canadian Journal of Public Health,* Vol. 74, March/April 1983.
122. House of Commons, Canada: *Time Lost: A demand for action on acid rain,* Report by the Subcommittee on Acid Rain, Ottawa: 1984.
123. Ibid.
124. *Toronto Globe and Mail:* 20 March 1984.
125. Environment Agency, Japan: *Quality of the Environment in Japan 1983,* Tokyo: Environment Agency, 1983.
126. Kelley, D.R., Stunkel, K.R. and Wescott, R.R.: *The Economic Superpowers and the Environment,* San Francisco, 1976.
127. Environmental Protection Agency: *Abatement for Stationary Sources in Japan,* Washington DC: US EPA, 1978.
128. Environment Agency, Japan: *Quality of the Environment in Japan 1977,* Tokyo: Environment Agency, 1977.
129. OECD: *Control Technology for Nitrogen Oxides in the Atmosphere,* Environment

Committee Air Management Policy Group, Paris: OECD, 1981.

130. Hardoy, J.E. and Satterthwaite, D.: "Third World cities and the environment of poverty", Washington DC: Background paper for the Global Possible Conference, 1984.
131. Ibid.
132. McAuslan, P.: *Urban land and shelter for the poor,* London: Earthscan, 1985.
133. UNIDO: *A statistical review of the World Industrial Situation in 1980,* UNIDO, 1981.
134. World Bank: *World Development Report,* Washington DC: 1983.
135. Smil, V.: *The Bad Earth: Environmental Degradation in China,* New York: Sharpe Zed, 1984.
136. Gennino, Angela and Shorrock, Tim: "South Korea: Paying a High Price for an 'Economic Miracle'", in *Not Man Apart,* July 1982.
137. Smil, V., op. cit.
138. Kinzelbach, W.K.H.: "Environmental Problems in the People's Republic of China", Paper presented to the Third International Conference on Energy Use Management, West Berlin, 1981.
139. Qin Ling: "A Discussion of China's Environmental Protection Technology", in *Renmin Ribao* (People's Daily), 4 August 1981.
140. Jernelov, Arne: "Acid rain and sulfur dioxide emission in China", in *Ambio,* Vol. 12, No. 6, 1983.
141. Ibid.
142. Smil, V., op. cit.
143. Sadullo, Jaime R.: "The threat of acid rain", in *Kapaligiran* (Newsletter of the Philippine Federation for Environmental Concern), Vol. III, No. 2, 1984.
144. Sahabat Alam Malaysia: *The State of the Malaysian Environment 1983-84,* Penang: SAM, 1983.
145. Sani, Sham: "Urbanisation and the atmospheric environment in SE Asia". Paper presented to Seminar on Problems of Development, Environment and the Natural Resource Crisis in Asia and the Pacific, Penang, Malaysia: October 1983.
146. Ibid.
147. Sahabat Alam Malaysia, op. cit.
148. Ibid.
149. Centre for Science and Environment: *The State of India's Environment: A Citizen's Report,* New Delhi: 1983.
150. Sharma, A.K.: "Environmental Pollution in India", in *Mazingira,* Vol. 7, No. 1, 1983.
151. Hardoy, J.E. and Satterthwaite, D., op. cit.
152. *The Star* (Johannesburg): 15 February 1985.
153. Ibid.
154. Ibid.
155. ZCCML: "Environmental issues in the copper mining industry of Zambia", unpublished paper, May 1984.
156. Perera, N.P.: "Environmental problems of copper mining and refining in Zambia", in *Industry and Environment,* Vol. 5, No. 1, March 1982.
157. Achayo Were, Paul T.: "The Development of Road Transport in Africa and its Effects on Land Use and Environment", in *Industry and Environment,* Paris: UNEP, April-June 1983.
158. Hardoy, J.E. and Satterthwaite, D., op. cit.
159. Muello, Peter: "Acid rain in Latin America", in *Acid News,* No. 1, March 1985.
160. Ibid.
161. Yague, Eloy: "Venezuela: acid rain 'a potential problem'", Rome: IPS, 1983.
162. Muello, Peter, op. cit.
163. *The Citizen,* Ottawa: 3 October 1984.
164. Kerr, Richard A.: "Pollution of the Arctic atmosphere confirmed", in *Science,* Vol.

212, 29 May 1981.
165. Ibid.
166. Kemf, Elizabeth: "Acid rain in the Arctic", in *World Wildlife Fund News*, No. 27, January/February 1984.
167. Wetstone, G.E. and Rosencranz, A., op. cit.
168. Dudley, N., Barrett, M. and Baldock, D., op. cit.

Further reading

US NATIONAL RESEARCH COUNCIL. *Acid deposition: Atmospheric Processes in Eastern North America.* Washington: National Academy Press, 1983.

DUDLEY, Nigel, Barrett, Mark, and Baldock, David. *The Acid Rain Controversy.* London: Earth Resources Research, 1985.

ENVIRONMENTAL RESOURCES LIMITED. *Acid Rain: A review of the phenomenon in the EEC and Europe.* London: Graham and Trotman, 1983.

WORLD RESOURCES INSTITUTE. *The American West's Acid Rain Test.* Washington: World Resources Institute, 1985.

SWEDISH MINISTRY OF AGRICULTURE. *Acidification Today and Tomorrow.* Stockholm: Ministry of Agriculture, 1982.

WEST GERMAN INTERIOR MINISTRY. *Report of the Causes and Prevention of Damage to Forests, Waters and Buildings by Air Pollution in the Federal Republic of Germany.* Bonn: Federal Ministry of the Interior, 1984.

ELSWORTH, Steve. *Acid Rain.* London: Pluto Press, 1984.

HOUSE OF COMMONS ENVIRONMENT COMMITTEE. *Fourth Report: Acid Rain.* London: Her Majesty's Stationery Office, 1984.

WETSTONE, Gregory S., and Rosencranz, A. *Acid Rain in Europe and North America.* Washington: Environmental Law Institute, 1984.

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Acid rain is not just about German forests and Canadian lakes. India's Taj Mahal is dissolving in an acid wind. Air pollution in Mexico City threatens "collective hysteria", warns the mayor. And soils in southern Brazil are turning acid. Wherever there is heavy industry or road traffic, acid pollution is a danger.

Nor is it just about rain. It comes as snow, fog, mist, and on the wind in clouds of dust and gas. It leaves dead forests, sterile soils, polluted rivers, crop losses and corroded buildings. It has become perhaps the most pressing and most universal environmental threat of the century. And it is getting worse.

Acid earth: the global threat of acid pollution is the first global study of acid pollution. It overturns the view that acid rain is solely a West European or North American phenomenon. It describes causes and effects, political implications and the controls already available. And country case studies from every continent confirm the alarming breadth of the crisis. Acid pollution is reported in Zambia and South Africa, Malaysia and Venezuela, and even in the Arctic, where haze has turned experimental filters black.

Winds carry acid across borders, creating international tension. US emissions – and US unwillingness to do anything about them – is straining relations with Canada. Britain is chastised by Sweden and Norway for refusing to act. Mexico and the United States trade sulphur emissions, and China may be exporting them to Japan. But acid pollution in Eastern Europe is also offering new opportunities for East-West cooperation.

Acid earth, written by John McCormick of Earthscan, argues that the causes of acid pollution are now well understood, and the methods of controlling it are widely available. There is little excuse for not beginning to de-acidify the earth.

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